Vol. XIII. — No. 9. September 1931.

BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[621. 134]

Application of Marbec's theory of kinetic diagrams to the determination of the velocities and accelerations of the different articulations of valve gear, (1)

by Pierre PLACE,

Chief Engineer, « Office Central d'Études de Matériel de Chemins de fer » (O. C. E. M.), Paris).

Figs. 1 to 33, pp. 733 to 760.

INTRODUCTION.

In designing locomotives, it is rarely possible, if we except the boiler, to establish the dimensions of the various parts, that is to say, to ascertain their fatigue, by any calculation that is at all exact, because we are more or less ignorant of the forces which are applied to them.

In regard to the axles and the frame, we are entirely ignorant of the reactions caused by the track.

In regard to the motion, piston and driving and coupling rods, we know the stresses due to the effect of the steam, but we do not know in what manner they are distributed between the various wheels, and we are obliged to make assumptions and to take the most unfavourable.

The valve gear has been studied very completely from the geometrical point of view, but practically not at all from the kinetic and dynamic points of view. The sections of its various parts and the shapes and dimensions of its supports are fixed empirically. It is therefore no infrequent occurrence for some valve gears to give rise to somewhat serious drawbacks at high speeds. The stresses exerted on these motions are almost ex-

(1) Translated from the French.

clusively stresses of inertia which we are not in the habit of calculating.

In a short time, when the locomotive test bed, the construction of which we proposed as far back as 1920, has been built by the O. C. E. M. (Office central d'études de matériel de chemins de fer), it will be possible to study by the stroboscopic method, with the « Stroborama » for example, the deflections at high speeds of the parts of the valve motion, which will provide an idea of some of these stresses. This method of investigation, although very valuable, is still incomplete.

We suppose that the stresses of inertia are not calculated because it is thought that there is no convenient method of determining the acceleration of the points of the various parts. There is, however, a general method, a graphical method due to the late marine engineer Marbec. If this method is not employed, it is either because it is not sufficiently well known, or because it is thought, wrongly, to be too complicated.

We thought that it would be of interest to make this method better known, to show that its application is easy in the general case, and that the difficulty which is encountered in applying it to the special case of the motion of a slide block in a link is not insurmountable.

For this purpose, we have applied the method to a concrete example, that of the two connected valve gears, high pressure and low pressure, of the Paris-Lyons-Mediterranean *Mountain* locomotive.

The only difficulty which arises is due to the fact that the slide block is not fixed in the link. It would be of interest to make the same study while neglecting this movement and considering the slide block as fixed in the link, which would be a simplification. It is probable that the results would be of the same order of magnitude, and this order of magnitude is the only thing which matters.

In the following, we shall recall the principle of the general method. We shall then show its application to the Walschaerts valve gear of the *Mountain* locomotive and finally we shall give the diagram of its application to the example chosen and evaluate the degree of precision obtained by the diagrams.

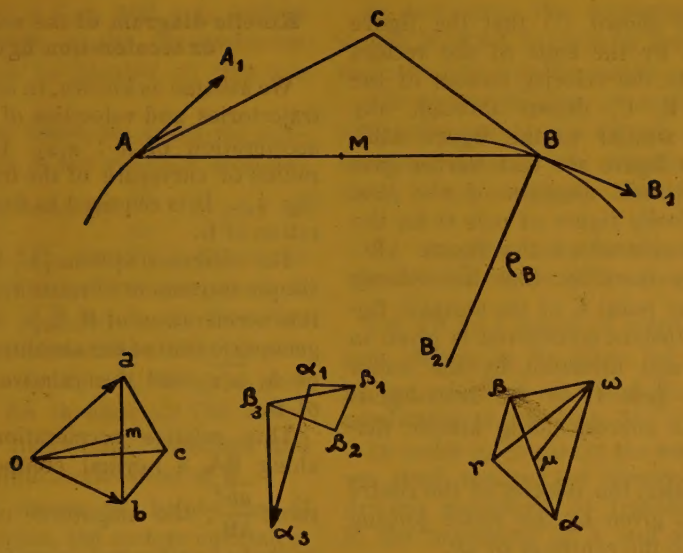
Mr. Tongas, Inspector at the O. C. E. M. has kindly drawn the diagrams and dealt with the last point.

The accelerations of the different points of the linked system being thus known, there still remains to determine the reactions exerted on the ends of any rod, taking into account the forces of inertia of all the other parts and the external forces (effect of the steam, friction) and finally to determine the fatigue at any point of a part.

REVISION OF GRAPHICAL KINETICS AND THEORY OF KINETIC DIAGRAMS.

The movement of a plane figure of invariable shape in its plane is entirely defined geometrically if the trajectories of two of its point A and B are known. As to the kinetic law of the movement on the trajectory, it can only be selected arbitrarily for one alone of these points, A for example, inasmuch as when the position of A is fixed in its trajectory, that of B follows on its own.

Thus, given the trajectory of the



Kinetic diagram of velocities.

Kinetic diagram of accelerations.

Fig. 1.

points A and B, and the kinetic law of the movement of A (that is to say, if we know the velocity and acceleration of A at each instant), it ought to be possible to deduce therefrom the velocity and acceleration of B at each instant, and then of any point connected invariably to A and B.

Kinetic diagram of the first order or the velocity figure.

Given (figure 1) :

the invariable figure ABC;

the trajectory of A and its velocity at a given instant t represented by the vector $\overline{AA_1}$;

the trajectory of B.

We are seeking the velocity $\overline{BB_1}$ of B at the same instant.

If through any point O in the plane. the vectors $\overline{oa}$ and $\overline{ob}$ are drawn respectively equivalent to $\overline{AA_1}$ and $\overline{BB_1}$, the latter being assumed to be known, *ab* represents the relative velocity at the instant t of B with respect to a system [A] driven with A in a movement of translation. But the relative movement of B with respect to this system is a rotation about A *since the length AB is constant;* the relative velocity $\overline{ab}$ is therefore perpendicular to AB which, when AA_1 is known, or $\overline{oa}$ in magnitude, direction and sense, and the *direction* BB_1 or $\overline{ob}$, to deduce $\overline{ob}$ by drawing $\overline{ab}$ perpendicular to AB.

It can be shown (1) that the figure *abc* formed by the ends of the vectors equivalent to the velocity vectors of the points A, B, C, drawn through any point O is similar to the figure ABC. It is to this figure *abc* that Marbec gave the name *kinetic diagram of the first order* or *velocity figure* of pole O for the position considered of the figure ABC. We can say therefore that the velocity vector of any point C of the movable figure, at the instant considered is given in magnitude and direction by the vector joining the pole O to the homologous point of the corresponding kinetic diagram.

In particular, the velocity of the centre M of AB is given by the vector joining the pole O to the centre *m* of *ab*.

It may also be remarked that, since the figures ABC and *abc* are similar and that the homologous straight lines AB and *ab* are at right angles to each other, all the other pairs of homologous straight lines AC and *ac*, BC and *bc* are also at right angles to each other.

Kinetic diagram of the second order or acceleration figure.

We assume as known, in addition to the trajectories and velocities of A and B, the acceleration of A : $\overline{\alpha_1\alpha_3}$. Let ρ_b be the radius of curvature of the trajectory of B (fig. 1.). It is required to find the acceleration of B.

The reference system [A] being given a simple movement of translation, the absolute acceleration of B, $\overline{\beta_1\beta_3}$ is merely the geometric sum of the absolute acceleration of A, $\overline{\alpha_1\alpha_3}$ and the relative acceleration of B.

This relative acceleration of B has, along BA, a normal component of the value $\frac{\overline{ab}^2}{\overline{AB}}$, the magnitude of which may easily be constructed geometrically or calculated, and which may be measured off in the direction from B to A on the line $\beta_1\alpha_1$ drawn through α_1 parallel to BA. The tangential component of the relative acceleration of B is perpendicular to the preceding component.

It will thus be seen that by the geo-

---

(1) Let a figure F move in its plane.

Let AB, A′B′ (fig. 2) be two positions infinitely near the segment AB the motion of which defines that of the figure F.

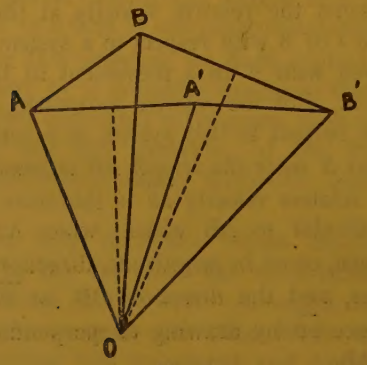


Fig. 2.

The vectors AA′, BB′ are proportional to the velocities of A and B.

AB may be brought to A′B′ by a rotation about O (point of intersection of the perpendiculars from the centres of AA′ and BB′), the triangles OAB and OA′B′ being equal, as their three sides are equal.

The triangles OAA′, OBB′ are similar, whence we deduce that the angle made by AA′ with BB′ is equal to the angle AOB, and that

$$\frac{AA'}{OA} = \frac{BB'}{OB} = k.$$

It follows from this that if vectors equivalent to AA′ and BB′... are drawn from any point, the ends of these vectors will form a figure directly similar to the figure F, the ratio of similitude being k.

metric addition of $\beta_1\alpha_1$ and $\alpha_1\alpha_3$, and by drawing through α_3 the perpendicular to BA, β_3 must be situated on this late straight line.

On the other hand, we know the normal component of the absolute acceleration of B; its value is $\frac{\overline{ob}^2}{\rho_B}$. It may be constructed as $\overline{\beta_1\beta_2}$, parallel to BB_2 in the sense BB_2 : the tangential component is perpendicular to $\beta_1\beta_2$; β_3 is therefore located at the intersection of this perpendicular drawn through β_2 with the perpendicular to BA through α_3. The vector $\overline{\beta_1\beta_3}$ gives in magnitude, direction and sense the absolute acceleration of B.

It may be shown as before that, if through any point, the vectors equivalent to the acceleration vectors are drawn, the figure $\alpha\beta\gamma$. . formed by the ends of these vectors is similar to the figure *abc* and consequently to the figure ABC.

This figure $\alpha\beta\gamma$... (fig. 1.) constitutes the *kinetic diagram of the second order* of pole ω for the position considered of the figure ABC... And we have just seen how the acceleration vector $\overline{\beta_1\beta_3}$ of the point B may be deduced from that $\overline{\alpha_1\alpha_3}$ of the point A.

It is merely necessary to draw through ω vectors $\overline{\omega\alpha}$ and $\overline{\omega\beta}$ equivalent to these two accelerations and to construct on $\alpha\beta$ a figure similar to the figure ABC... in order to obtain the kinetic diagram of the second order $\alpha\beta\gamma$...

The acceleration vector of any point C of the movable figure, at the instant considered, is given in magnitude, direction and sense by the vector having the pole ω for its origin and for its end the homologous point γ of the corresponding kinetic diagram of the second order.

In particular, the acceleration of the centre M of AB is given by the vector joining the pole ω to the centre μ of $\alpha\beta$.

The kinetic diagram of accelerations is not *orthogonal* to the *kinetic diagram of velocities* because the magnitude of the latter is not constant.

Another construction for the determination of the accelerations.

Let AB be a figure of constant magnitude sliding in its plane, let $\overline{oa}$ and $\overline{ob}$ be the velocities of A and B; $\overline{ab}$ is perpendicular to AB (fig. 3).

In order to construct the accelerations, we shall resolve the movement into a driving movement of translation equal to the movement of A and an instantaneous rotation ω.

$$\omega = \frac{ab}{AB}.$$

The driving movement being a translation, there is no complementary acceleration and the acceleration of B is equal to the geometric sum of the acceleration of A and the relative acceleration of B in the movement of rotation.

The relative acceleration of B may be resolved into a normal or centripetal acceleration

$$\gamma_c = \omega^2 AB$$

and a tangential acceleration

$$\gamma_t = AB\,\frac{d\omega}{dt}.$$

If the vector $\overline{\alpha\alpha'}$ represents the acceleration of the point A, which acceleration is assumed to be known, we shall obtain that of the point B by adding to the vector $\overline{\alpha\alpha'}$ at its end α' the vectors γ_c parallel to AB from *B towards A*, and γ_t perpendicular to AB (fig. 4).

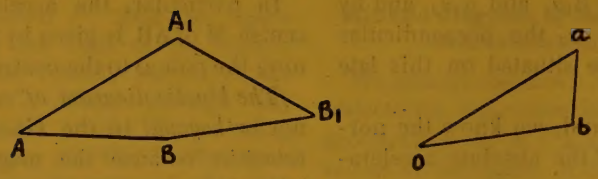


Fig. 3.

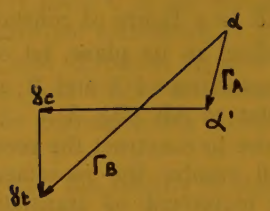


Fig. 4.

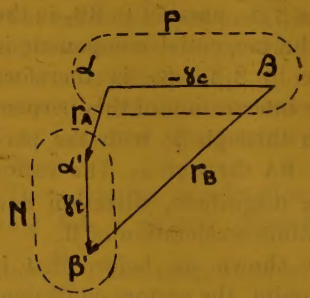


Fig. 5.

It comes to the same as drawing, from the origin α of the vector $\overline{\alpha\alpha'}$, the vector $-\gamma_c$, that is $\overline{\alpha\beta}$, consequently parallel and proportional to AB and *in the same sense as it* (fig. 5); then from the end α' of the vector $\overline{\alpha\alpha'}$ the vector γ_t, that is $\overline{\alpha'\beta'}$; this vector is perpendicular and proportional to AB.

$\beta\beta'$ is the acceleration required.

It will be seen that the points $\alpha\beta\ldots$ form a figure P parallel to the movable figure and similar in the ratio $\omega_2 = \left(\frac{ab}{AB}\right)^2$ and that the points such as $\alpha'\beta'\ldots$ form a figure N perpendicular to the movable figure and similar in the ratio $\frac{d\omega}{dt}$.

The accelerations are obtained by joining the homologous points $\beta\beta'$ of the two figures

It is convenient to employ :

The capital letters A, B ..... for the points of the movable figure.

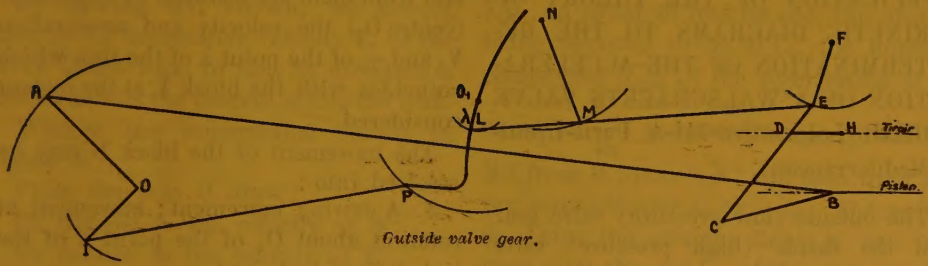
The small letters *a*, *b* ..... for the points of the velocity figure.

The letters $\alpha, \beta, \ldots$ for the points of the figure P.

The letters $\alpha'\beta'\ldots$ for the points of the figure N.

Articulated systems.

An articulated system is composed of invariable figures having invariable common points in each of them. If the velocity and acceleration figures, relative to the invariable parts of these systems are considered, they form chains of figures which are deformed while remaining similar individually to themselves. The ratio of similitude varies from one figure to the other, the connection merely imposing identical values for the velocity and acceleration of the points of articulation supposed to belong to each of the two figures.



Outside valve gear.

Fig. 6.

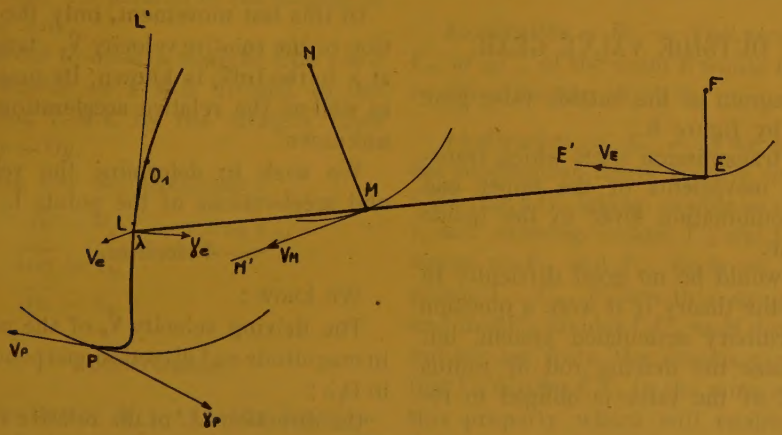


Fig. 7.

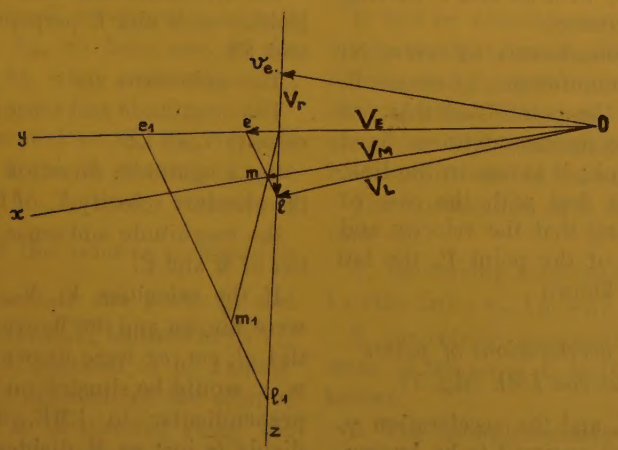


Fig. 8.

APPLICATION OF THE THEORY OF KINETIC DIAGRAMS TO THE DETERMINATION OF THE ACCELERATION OF A WALSCHAERTS VALVE GEAR (Locomotive 241-A, Paris-Lyons-Mediterranean).

The outside (low pressure) valve gear and the inside (high pressure) valve gear are connected on one and the same side of the locomotive.

I. — OUTSIDE VALVE GEAR.

The diagram of the outside valve gear is given by figure 6.

F is a transmission shaft which transmits the movements of the upper end of the combination lever to the inside valve gear.

There would be no great difficulty in applying the theory if it were a question of an ordinary articulated system, but in this case the driving rod or radius rod LME of the valve is obliged to remain :

At L on the link O_1P, which oscillates about the axis O_1 with its end P moving over a circumference;

At M on a circumference of centre N;

At E on a circumference of centre F.

Consequently, the point L of this rod cannot remain coincident with a fixed point λ of the link; it moves in the link.

We shall first deal with the case of this rod, assuming that the velocity and the acceleration of the point P, the tail of the link, are known.

Velocities and accelerations of points of the radius rod LME (fig. 7).

The velocity V_P and the acceleration γ_P of the point P are assumed to be known, and from them are deduced by similitude (centre O_1) the velocity and acceleration V_e and γ_e of the point λ of the link which coincides with the block L at the instant considered.

The movement of the block L may be resolved into :

1. A driving movement: movement of rotation about O_1 of the point λ of the link defined by V_e and γ_e.

2. A relative movement on the link.

Of this last movement, only the direction of the relative velocity V_r, tangential at λ to the link, is known. Its magnitude as well as the relative acceleration γ_r are unknown.

We wish to determine the velocities and accelerations of the points L, M, E.

Velocities.

We know :

The driving velocity V_e of the point λ, in magnitude and direction, perpendicular to $O_1\lambda$;

the direction LL′ of the relative velocity V_r of L;

the directions MM′ and EE′ of the velocities of M and E perpendicular to NM and FE.

The unknowns are :

The magnitude and sense of the relative velocity V_R of L;

the magnitude, direction and sense of the absolute velocity V_r of L;

the magnitude and sense of the velocities of M and E.

If the velocities V_L, V_M, V of L, M, E were known and the figure of the velocities *ol*, *om*, *oe* were drawn, the points *l*, *m*, *e*, would be situated on a straight line perpendicular to LME, and *m* would divide $\overline{le}$ just as M divides $\overline{LE}$.

By drawing $\overline{OV_e}$ known, we should have in $V_e l$ the relative velocity V_r of the block in the link. In fact, its direction is known as it is the tangent at λ to the link.

Whence the construction shown in figure 8.

From the pole O draw :

Ox parallel to the velocity of M;

Oy parallel to the velocity of E;

Ov_e equivalent to the velocity at which λ is driven; $v_e z$ parallel to the tangent at λ to the link.

It suffices to draw a straight line $l\ m\ e$ perpendicular to L M E divided in the proportion L-M-E by the straight lines $v_e z - Ox - Oy$.

In this way we determine :

$$\overline{Ol} = V_L \qquad v_e l = V_r$$
$$\overline{Om} = V_M$$
$$\overline{Oe} = V_E$$

Accelerations.

Acceleration of M. — Let the acceleration of L be assumed to be known, say Γ_L.

Knowing the trajectory of M and in particular its radius of curvature ρ_M as well as the velocity V_M, we have seen in the preliminaries, by what construction Γ_M may be found :

On a line parallel to ML (fig. 10) and in the sense from M towards L, we measure off the normal component $\mu_1\lambda_1 = \frac{\overline{lm}^2}{\overline{LM}}$ of the relative acceleration of M with respect to the point L, and from λ_1 the vector $\overline{\lambda_1\Gamma_L}$ equivalent to Γ_L, acceleration of L assumed to be known. The tangential component of the relative acceleration of M is directed along the perpendicular Δ_L droppel from Γ_L onto $\lambda_1\mu_1$. In order to find its end, the origin being assumed to be at Γ_L, the normal component $\overline{\mu_1\mu_2}$ of the acceleration of M equal to $\frac{\overline{V_M}^2}{\rho_M}$ is drawn from μ_1, parallel to MN from M towards N; and then from μ_2 the perpendicular Δ_M to $\mu_1\mu_2$. The point at which the straight lines Δ_L and Δ_M meet gives the end Γ_M of the acceleration of M which is $\overline{\mu_1\Gamma_M}$.

Acceleration of E. — The acceleration Γ_E, as $\varepsilon_1\Gamma_E$, of the point E would be drawn in the same way (fig. 11).

Acceleration of L. — If we construct the acceleration figure relative to the rod LME (fig. 11), taking as pole ω the point λ_1 and drawing vectors Γ'_M and Γ'_E, equivalent to Γ_M and Γ_E, we know that the points Γ_L, Γ'_M, Γ'_E are in a straight line and that Γ'_M divides $\Gamma_L\Gamma'_E$ as M divides LE, but we see from the construction itself that Γ_M divides $\Gamma_L\Gamma_E$ in the same way. It is this property which will enable us to determine at once Γ_L, which is still unknown, Γ_M and Γ_E.

It will be remembered that Γ_M must be on the straight line Δ_M (fig. 10) which is known, and Γ_E on the analogous straight line Δ_E which is known, and that $\Gamma_L\Gamma_M\Gamma_E$ are on a straight line Δ_L perpendicular to LME and divided in the same proportion.

The acceleration of L is the geometric sum of :

1. the driving acceleration of the point λ of the link : γ_e, known;

2. the relative acceleration of the movement of the point L in the link : γ_r, unknown.

3. The complementary acceleration : γ_c wich may be determined as follows.

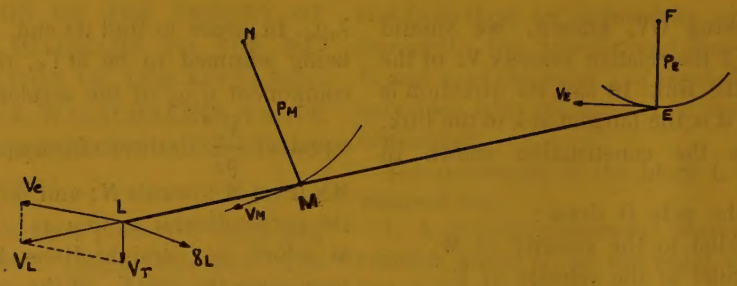


Fig. 9.

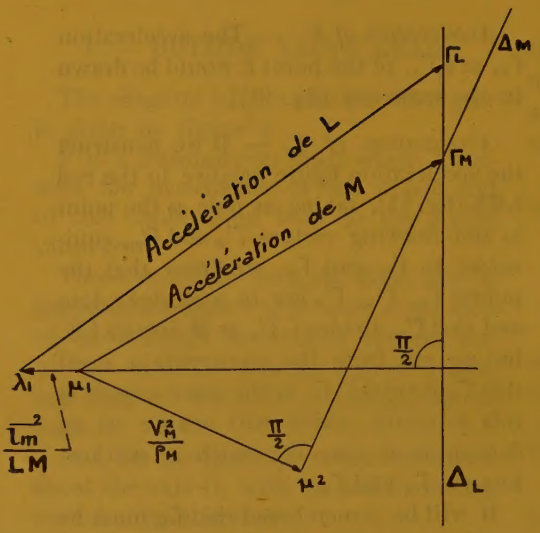


Fig. 10.

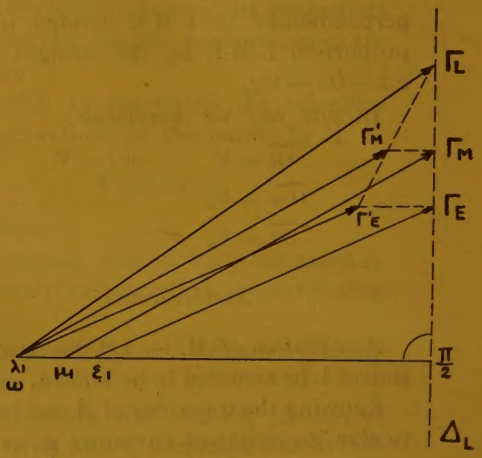


Fig. 11.

The driving movement of the block is the rotation of the link about its axis O_1.

We know in magnitude, direction and sense the relative velocity of L in the link, tangential at λ to the link.

According to the theorem of Coriolis (fig. 12) if OA is the vector representing the instantaneous rotation of the driving movement, ω the angular velocity, $\overline{OV}_r$ a vector equivalent to the relative velocity, making in the general case an angle α with the preceding vector, *the velocity of the point* V_r, *in the rotation* OA, *is half the complementary acceleration in magnitude, direction and sense.*

$$\gamma_c = 2\omega \cdot V_r \cdot \sin \alpha.$$

In the present case, $\alpha = \frac{\pi}{2}$ and the complementary acceleration is double the velocity of the end of a vector equivalent to the vector V_{rL} *transported to* O_1 in the driving movement of rotation of the link.

Construction of Γ_L (fig. 13). — Starting

from the pole of accelerations ω, the geometric sum of γ_e and γ_c will be made. The relative acceleration γ_r is unknown, but we know its normal component γ_{rn} parallel to the radius of the link passing through λ and equal to $\frac{\overline{V_{el}}^2}{R}$; this vector is added geometrically to the two preceding vectors. The end of Γ_L is on the perpendicular Δ_L to this last vector passing through its end.

After what was said in the foregoing, it only remains to determine a straight line perpendicular to LME divided by $\Delta_L\Delta_M\Delta_E$ in the proportion L-M-E in order to have the accelerations $\omega\Gamma_L$, $\omega\Gamma_M$, $\omega\Gamma_E$.

Velocities and accelsrations of the system : crank OA, rod AB, combination lever CDE, slide valve H. (Fig. 14).

Velocities.

A revolves about O with a uniform movement of angular velocity ω.

We know $V_A = \omega . OA$.

We have seen, assuming the velocity and acceleration of P, the tail of the link, to be known, how to determine V_E and γ_E, the velocity and acceleration of E which we shall now assume to be known.

Velocity diagram (fig. 15).

Through a pole O, $\overline{O_a}$ is drawn equivalent to V_A.

The velocity of B is directed along OB. Its relative velocity with respect to A is perpendicular to AB.

Trough *a*, *ab* is drawn perpendicular to AB and, through *o*, *ob* parallel to BO.

$\overline{ab}$ and $\overline{ob}$ will be the relative and absolute velocities of B.

The relative velocity of C with respect to B is directed along the perpendicular to BC. A locus of the end of the velocity vector of C will therefore be the perpendicular *bx* erected at *b* to the direction CB.

The representative point of F of which the velocity is zero is the pole O. O_e is drawn parallel and equal to V_E.

The relative velocity of C with respect to E is perpendicular to CE. Hence, the point *c* is on the perpendicular to CE drawn from *e*. It is thus situated at the point of intersection of this perpendicular with *bx*.

oc is the velocity of C.

The velocity of the point D will be obtained by seeking on *ce* the point *d* which divides *ce* as D divides CE; *od* is the velocity of D.

The relative velocity of H with respect to D is perpendicular to HD on *dy*, but the absolute velocity of H is directed along $X_1 X_2$. The point of intersection *h* of *dy* with the line drawn through O parallel to $X_1 X_2$ gives the absolute velocity *oh* of H.

Accelerations

We determine these accelerations by means of the figures P and N (see preliminary considerations).

The acceleration Γ of a point may be resolved into :

a normal acceleration Γ_N having the value $\frac{v^2}{\rho}$;

a tangential acceleration Γ_T having the value $\frac{dv}{dt}$;

v = velocity;

ρ = radius of curvature.

The diagram of normal accelerations N and then that of the tangential accelerations P will now be constructed. Let the pole be ω (fig. 16).

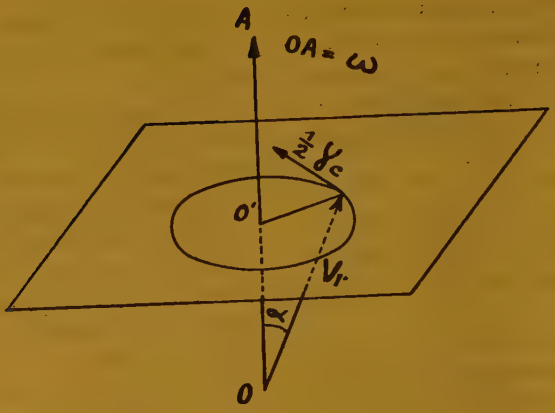


Fig. 12.

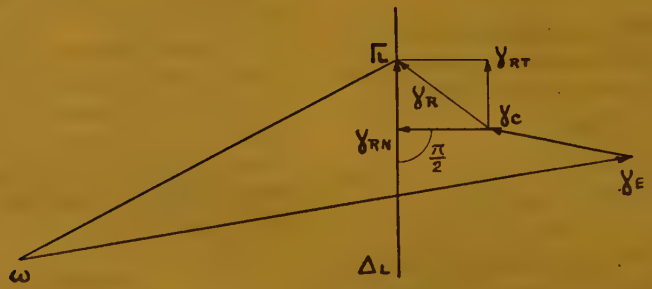


Fig. 13.

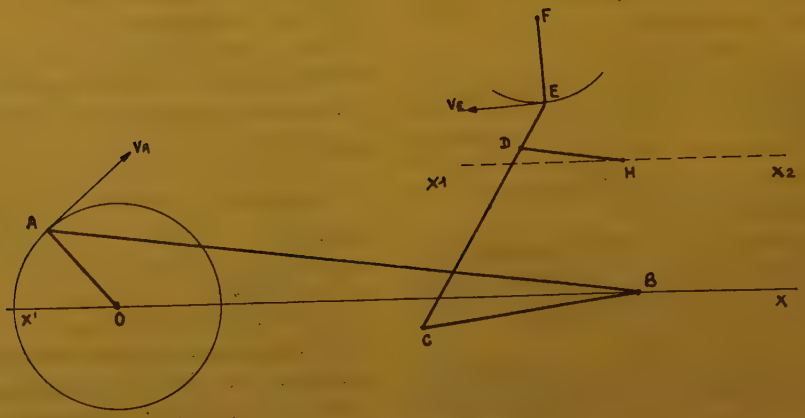


Fig. 14.

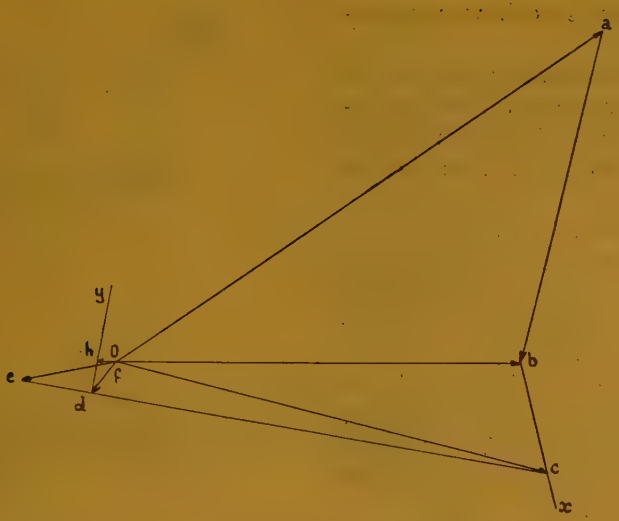


Fig . 15.

Normal accelerations.

$\omega\alpha$ parallel to OA and equel to $\frac{\overline{oa}^2}{\overline{OA}}$

$\alpha\beta$ parallel to AB and equal to $\frac{\overline{ab}^2}{\overline{AB}}$

$\beta\gamma$ parallel to BC and equal to $\frac{\overline{cb}^2}{\overline{CB}}$

$\gamma\varepsilon$ parallel to CE and equal to $\frac{\overline{ce}^2}{\overline{CE}}$

$\varepsilon\varphi$ parallel to EF and equal to $\frac{\overline{ef}^2}{\overline{EF}}$

δ is determined by $\gamma\delta = \frac{\overline{cd}^2}{\overline{CD}}$

wherein $\delta\varepsilon = \frac{\overline{ed}^2}{\overline{ED}}$

$\delta\xi$ parallel to DH and equal to $\frac{\overline{dh}^2}{\overline{DH}}$.

Tangential accelerations.

The movement of the point A being assumed uniform, the angular velocity ω is constant, and the tangential acceleration $\frac{d\omega}{dt}$ is consequently zero, therefore the acceleration of the point A is reduced to the normal acceleration $\omega\alpha$ and the point α' is at ω.

The total acceleration of B has BO for direction, and since, on the other hand, the tangential component is perpendicular to BA, and hence to $\alpha\beta$, the point β' is situated at the intersection of the line drawn through β parallel to BO, with the perpendicular to $\alpha\beta$ drawn through α'.

As regards the end γ' of the acceleration of C, we know a locus of it, namely the perpendicular to $\beta\gamma$ drawn through β', that is $\beta' x$.

It should be noted that the acceleration of F being zero, $\overline{\varphi\varphi'} = 0$; therefore, φ' is at φ, which may be of interest in other cases.

Starting out now from the point E, we know its acceleration in magnitude and

direction, and from ε we draw an equivalent vector $\overrightarrow{\varepsilon\varepsilon'}$.

The tangential acceleration with respect to C ought to pass through ε′ and be perpendicular to CE, and γ′ is obtained at the intersection of this perpendicular drawn through ε′ with $\beta' x$.

The acceleration of C is therefore $\gamma\gamma'$.

In order to obtain the acceleration of D, it is necessary to construct the acceleration figure relative to the indeformable system CBE.

Through a pole Ω, $\Omega\Gamma_C$ and $\Omega\Gamma_E$ are drawn equivalent to $\gamma\gamma'$ and $\varepsilon\varepsilon'$ (fig. 17); then, on the straight line $\Gamma_C\,\Gamma_E$ a point Γ_D is sought such that this point divides $\Gamma_C\,\Gamma_E$ as D divides CE.

$\Omega\Gamma_D$ is the acceleration of D. This acceleration is transferred to start from δ ; *the point δ′ ought, as a check, to be situated on the straight line γ′ε′.*

The total acceleration of H, the representative vector of which has its origin at ξ is parallel to X_1X_2.

The tangential acceleration of D with respect to H is directed along the perpendicular to DH drawn trough δ′.

ξξ′ is the total acceleration of H.

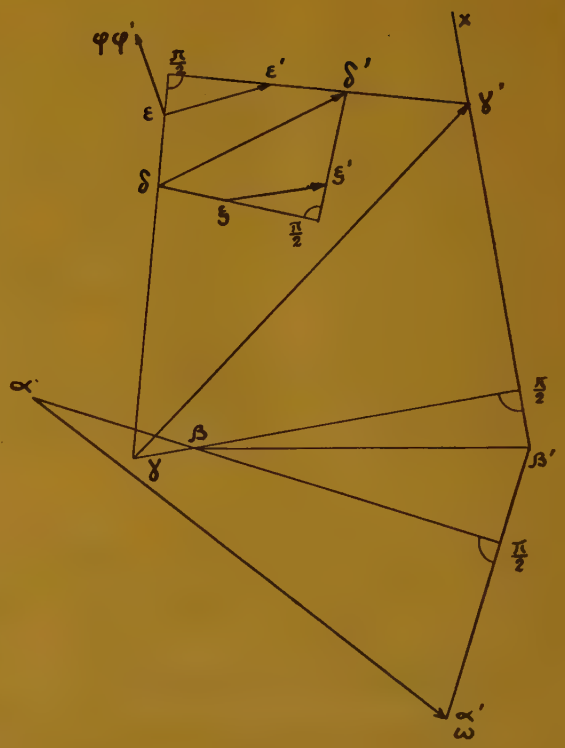


Fig. 16.

Velocities and accelerations of the system : eccentric crank OI, eccentric rod IP.

This system (fig. 18) is analogous to the system crank-connecting rod except that P moves on a circle O_1 instead of moving in a straight line passing through O.

Velocities .

We shall draw the velocity diagram (fig. 19). Let O be the pole, and let us draw Oi equivalent to the velocity of I :

$$V_1 = \omega.OI.$$

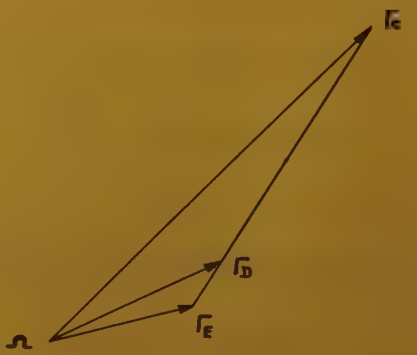


Fig 17.

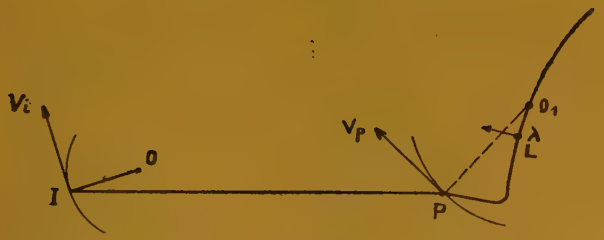


Fig. 18.

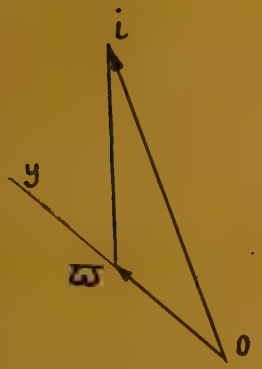


Fig. 19.

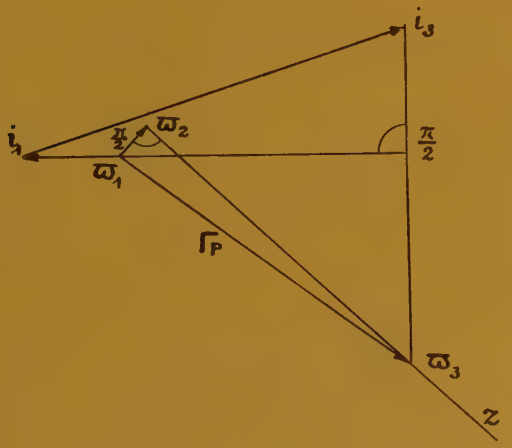


Fig. 20.

The velocity of P is directed along Oy perpendicular to O_1P.

The relative velocity of P with respect to [I] is perpendicular to PI; through i we draw the perpendicular to PI which cuts Oy in ω.

The velocity of P is $V_P = \overline{O\varpi}$.

The relative velocity of P with respect to [I] is equal to $i\varpi$.

Accelerations.

Method of figure 1.

We know the acceleration of I which is reduced to a normal acceleration $\Gamma_I = \frac{\overline{V_i}^2}{OI}$ since the movement is uniform.

We draw (fig. 20) $\overline{i_1 i_3}$ equivalent to Γ_I.

The relative acceleration of P with respect to I has a normal component $\frac{\overline{i\varpi}^2}{PI}$ directed from P toward I which we shall lay off on a line parallel to PI from P toward I so that its end comes to i_1, that is $\varpi_1 i_1$.

The required absolute acceleration of P has a normal component equal to $\frac{\overline{V_P}^2}{O_1P}$ which we shall lay off as $\overline{\varpi_1\varpi_2}$ in the sense PO_1, and a tangential component perpendicular to PO_1. We draw $\varpi_2 Z$ perpendicular to PO_1; the end of the acceleration Γ_P of P is on this straight line. We draw

through i_3 the perpendicular to PI which meets $\varpi_2 Z$ in ϖ_3. We have $\Gamma_P = \overline{\varpi_1 \varpi_3}$; $\varpi_2 \varpi_3$ is its tangential component.

II. — INSIDE VALVE GEAR.

The velocities and accelerations of the inside valve gear would be determined in the same way without difficulty, starting from :

1. The movement of the piston which

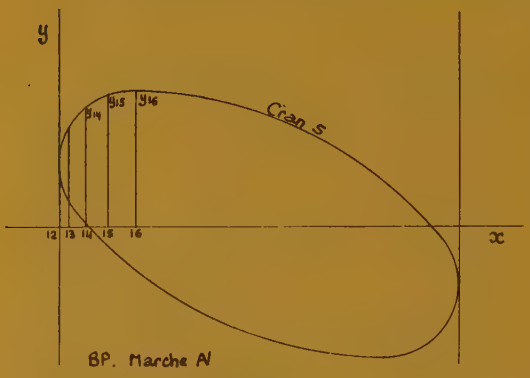


Fig. 21.

Explanation of French terms :
Cran 5 = Notch 5. – Marche AV = Forward running.

leads to the lower end of the inside combination lever and

2. The movement of the transmission shaft F which leads to the upper end of the same combination lever.

Diagram. — The diagram for the two valve gears, high and low pressure, is reproduced in figures 22 to 33.

The different constructions which compose this diagram have had to be drawn actually on scales different from one another as indicated by the note appended to figure 22.

The requirements for reproduction in the *Bulletin* have also resulted in different reductions (which moreover are not shown) for the different plates, and these reductions render it difficult to make direct comparisons between the constructions.

In order to enable the complete diagram to be reconstructed, we have drawn on each plate a reference line serving as a reference of orientation, the direction of each of these lines being that of the horizontal.

Each reference line is accompanied by the indication of a length. the length which it has on the original. After enlarging the figures so as to restore to each reference line the length indicated, the figure of the original diagram will be obtained, to which applies according to the case, the scale $\frac{1}{5}, \frac{1}{2\omega}, \frac{2}{\omega}, \frac{1}{\omega^2}, \frac{1}{2\omega^2}, \frac{5}{\omega^2}$ etc.

The notes on the construction accompanying these figures have been compiled for the use of the designing office. This explains their terseness and the fact that we did not wish to make them complicated by refering to the different vectors by name.

VERIFICATION OF THE RESULTS.

We have seen how the accelerations of the different articulations of the valve gear, leading closer and closer to that of the valve, are obtained.

It appeared of interest to compare the results obtained with those which may be obtained directly for the piston and the valve. This verification has been very satisfactory.

We obtained the velocities and accelerations of the different points for different positions of the mechanism of

the locomotive 241-A (forward running, admission notch 50-60, positions 0, 6, 12, 15). The results obtained are contained in the following table A. In order to obtain them directly for the valves, we employed the following procedure.

Direct determination of the velocity and acceleration of the valve for position 15 of the crank. (Fig. 21.)

Velocity.

The circle swept out by the crank is divided into 24 equal parts, starting from the dead centre. We assume the velocity of the valve to be constant in each of these intervals, and obtain, from the table of Fauveau ellipses constructed when the valve gear was designed, on the curve for admission notch 5, the distances E and E′ travelled by the valve during the intervals 14-15 and 15-16.

We have :

$$E' = y_{15} - y_{14},$$
$$E = y_{16} - y_{15}.$$

If we assume the angular velocity of the driving wheels to be 5 revolutions per second, then the mean velocity of the valve in each of these intervals will be :

$$V = (y_{15} - y_{14}) \times 24 \times 5.$$
$$V' = (y_{16} - y_{15}) \times 24 \times 5$$

We take as the value of the velocity at the point 15 :

$$V_{15} = \frac{V + V'}{2}.$$

It will be seen by referring to the table B below that the results obtained fairly agree with those obtained by the graphical method.

In the example selected, on eight determinations, the difference between the two values does only attain 10 % in one single case .

The arithmetic mean of the differences found is 0.042; the algebraic mean is — 0.029.

Acceleration.

We have been able to apply the same method, although with less precision, to the comparison of the accelerations for the valves.

We worked out the difference between the mean velocities of the valve in the two intervals encompassing the point considered :

$$\Delta V_{15} = V' - V.$$

By reducing this variation to unit time, we obtained an approximate value of the acceleration of the valve at the point 15

$$\Gamma_{15} = (V' - V) \times 24 \times 5.$$

The greatest differences we have found in proceeding thus attains 15 %. The arithmetic mean of the differences found is 0.697; the algebraic mean is — 0.009.

It will be seen that the precision of the graphic diagrams leads to a result very close to that which may be obtained directly (and in a likewise approximate manner) for the valve, despite the superposition of the errors. The precision of the diagrams (that of the method is absolute) therefore gives still closer results for the accelerations of the other articulations which cannot be obtained directly.

TABLE A.

Velocities and accelerations of the different points for the positions

POINTS.	0-24		6		12		15		15 (Angular velocity 10 π)	
	Velocities.	Accelerations.	Velocities.	Accelerations.	Velocities.	Accelerations.	Velocities.	Accelerations.	Velocities.	Accelerations.
Low pressure valve gear :									Metres per second.	Metres per second².
I.	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0 200	6.28	197.4
P	0.198	0.082	0.004	0.238	0.220	0.098	0.161	0.187	5.59	— 184.5
λ (driving).	0.050	0.020	0.001	0.063	0.053	0.025	0.041	0 048	1.28	— 47.4
L (relative movement).	0.000	0.017	0.0004	0.034	0.002	0.023	0.0137	0.009	0.43	— 8.9
L (absolute movement)	0.050	0.0065	0.0011	0.072	0 053	0.0036	0.042	0 040	1.31	— 39.5
M	0.050	0.0072	0.0011	0.072	0.053	0.0053	0.042	0.040	1.31	— 39.5
E	0.050	0.0112	0.0011	0.082	0.053	0.013	0.044	0.040	1.38	— 39.5
G	0.036	0.0081	0.0009	0.059	0.038	0.0089	0.0317	0.029	0.99	— 28.6
A	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	11.00	345.4
B (piston)	0.000	0.421	0.350	0.070	0.000	0.300	0.212	0.247	6.66	242.8
C	0.016	0.454	0.354	0.150	0.032	0.330	0.230	0.253	7.22	240.9
D	0.039	0.045	0.041	0.055	0.047	0.0325	0.016	0 063	0.50	— 62.1
H (valve).	0.039	0.044	0.041	0.054	0.046	0.0320	0.014	0.062	0.44	— 61.1
High pressure valve gear:										
A'	0 325	0.325	0.325	0 325	0.325	0.325	0.325	0.325	10.21	320.8
B' (piston)	0.000	0.388	0.325	0.064	0.000	0.389	0.247	0 251	7.76	247.7
C'	0 022	0.456	0.324	0.150	0.018	0.430	0.251	0.242	7.90	238.8
G	0.036	0.0081	0.0009	0.059	0.038	0 0089	0.0317	0.029	0.99	— 28.6
E'	0.034	0.0093	0.0009	0.060	0.036	0.0080	0.0288	0.030	0.90	— 29.6
D'	0.030	0.063	0.040	0.055	0.032	0.055	0.011	0.062	0.35	61.2
H' (valve)	0.030	0.054	0.040	0.054	0.032	0.051	0.0035	0.061	0.11	60.2

Note. — If ω denotes the angular velocity, the velocity and acceleration of each point will be given in metres by multiplying the numbers in the above table : 1. for the velocities, by ω ; 2. for the accelerations by ω^2. By way of example, we give in the last column on the right, the values obtained for the position 15 by assuming the velocity ω to be equal to 5 revolutions per second or 10 π. We have placed the minus sign in front of those accelerations which tend to cause the velocity to decrease.

TABLE B.

Velocity and acceleration of the valve.

Calculated : 1. Graphically by the method of kinetic diagrams ;
2. With the aid of measurements made on the Fauveau ellipse.

241-A. Notch 5, Forward running.

POSITIONS.		0-24		6		12		15	
		V m-s	Γ m-s²	V m-s	Γ m-s²	V m-s	Γ m-s²	V m-s	Γ m-s²
High pressure valve gear.	Kinetic diagrams. . .	0.94	43.43	1.29	45.40	1.005	50.00	0 11	60.21
	Fauveau ellipse.	0.93	43.60	1.20	40.80	1.02	57.60	0.095	57.60
Low pressure valve gear.	Kinetic diagrams. . .	1.23	53.30	1.26	53.30	1.45	31.58	0.44	61.14
	Fauveau ellipse. . . .	1.26	57.60	1.275	46.80	1.45	28.80	0.41	64.80

(See **Application** on pages 760 to 770 hereafter).

Application of Marbec's theory of kinetic diagrams.

Velocities and accelerations of the different articulations of the mechanism.

Locomotive 241 A

Notch 50-63 — Forward running — Position 15.

Fig. 22. — Low pressure valve gear (outside).

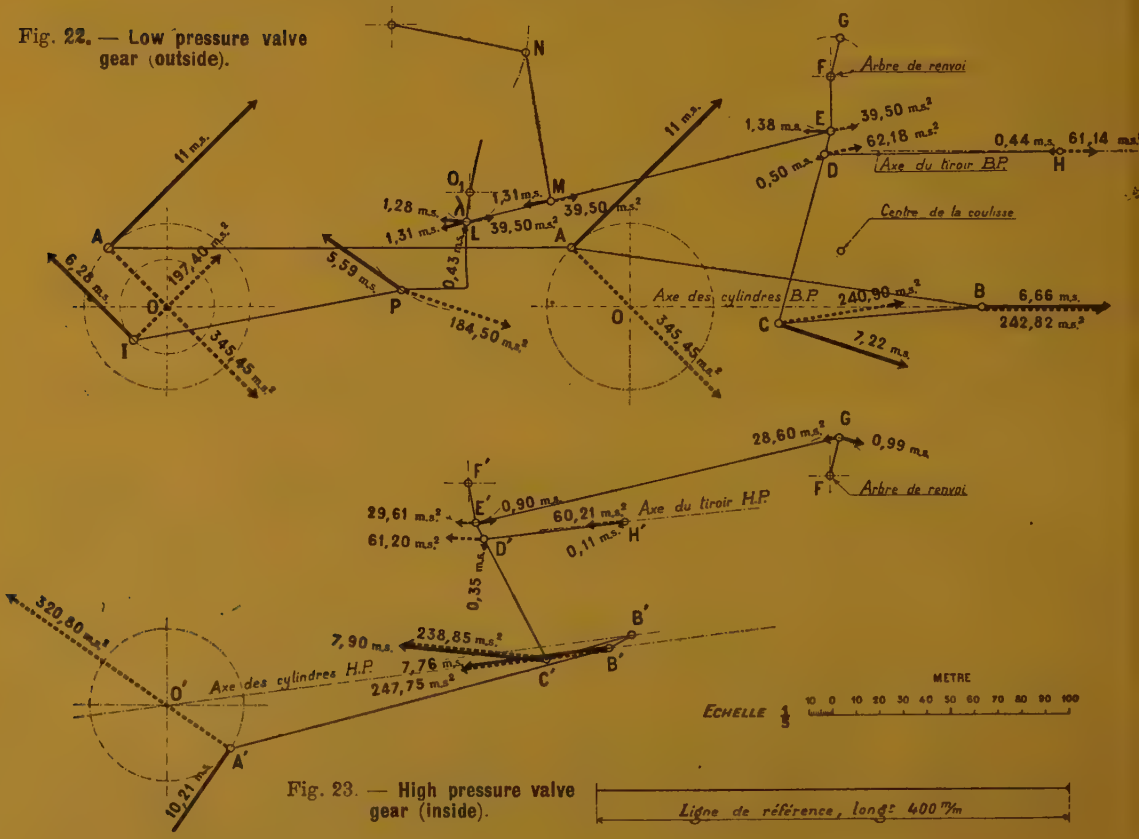


Fig. 23. — High pressure valve gear (inside).

Ligne de référence, longr 400 m/m

Figs. 22 and 23.

Explanation of French terms in figs. 22 and 23 :

Arbre de renvoi = Transmission shaft. -- Axe des cylindres B. P. = A is of low-pressure cylinders. — Axe des cylindres H. P. = Axes of high-pressure cylinders. — Axe du tiroir = Axis of valve. — Centre de la coulisse = Centre of link. -- Echelle = Scale. — Ligne de référence, longr. 400 m/m. = Reference line, length 400 mm.

REMARKS.

I. The magnitudes which are to be represented being very different, it is not always possible to select a single scale for all the figures.

It is to be understood, therefore that, when for the sake of brevety we say, for example figure 25, draw OVλ equivalent to Oλ of figure 24, we are nevertheless obliged to take different scales for these two vectors.

This necessity is experienced for the accelerations in particular.

Independently of the scale selected for each figure, the velocities are represented on the scale $\frac{1}{\omega}$, and the accelerations on the scale $\frac{1}{\omega^2}$, where ω is the constant angular velocity of the driving wheels.

Thus, a single construction furnishes the velocities and accelerations at the different running speeds by simply multiplying by ω or ω^2 the values measured on the scale of the figures. The numerical values given for the position considered, correspond to a velocity of 5 revolutions per second.

II. The velocity and acceleration of the valve can only be determined by a series of rather difficult constructions which do not appear to admit of final verification. It appeared of interest to us to obtain one.

1. *Velocity of the valve.* — The mean velocities of the valve during the intervals 14-15 and 15-16, if for example the position considered is 15, are calculated on the Fauveau ellipse. Their mean gives the value found here with a very satisfactory precision.

2. *Acceleration* — The difference between these two mean velocities is obtained, and by reducing it to 1 second, the acceleration at the point 15 is deduced with an error which may attain 10 to 15 %.

Legend :

Draw O*i* equivalent to the velolity of 1

This velocity is equal, for the velocity of rotation ω, to the real magnitude of 01 × ω.

By means of the scale of figure 22, the real magnitude of OI may be found to be 200 mm. The velocity of I is 200.ω ; as the scale of figure 24 is $\frac{1}{2\omega}$, we put O*i* equal to $\frac{200\ \omega}{2\ \omega} = 100$ mm.

Trough *i* draw the perpendicular to IP.

Through O draw the parallel to the tangent at P to the circumference O_1. These two straight lines intersect at *p*

op is the velocity of P.

Construct on *op* a triangle similar to $O_1p\lambda$.

*o*λ is the velocity of the point λ of the link.

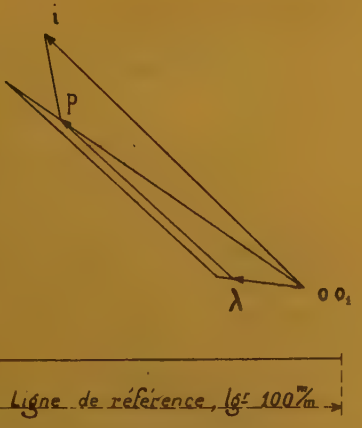


Fig. 24. – Velocities of the points P and λ of the link.

Scale $\frac{1}{2\omega}$

Note. — Ligne de référence, lgr. 100 m/m = Reference line, length 100 mm.

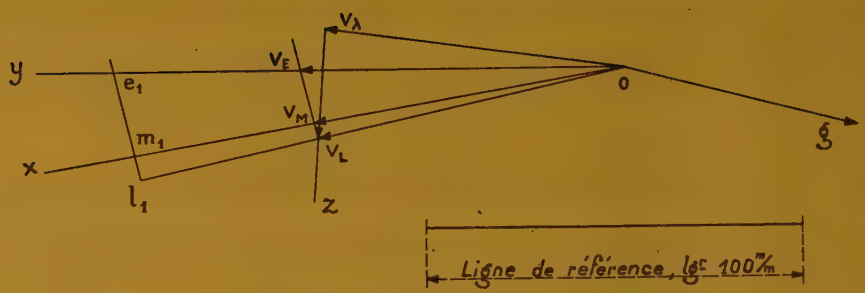


Fig. 25. — Velocities of the points L, M, E. of the radius rod and of the point G of the transmission shaft of the motion to the high pressure gear. Scale $\frac{2}{\omega}$.

Legend :

Draw Ox perpendicular to NM ;
Oy perpendicular to FE ;
$OV\lambda$ equivalent to $O\lambda$ of figure 24.

The scale of figure 25 being four times as great as that of figure 24, OV_λ is in reality equal to four times $O\lambda$.

Draw trough V_λ the parallel $V_\lambda Z$ to tangent at L to the link.
Draw a perpendicular to LME divided by Ox, Oy, $O_\lambda Z$ as the points L, M, E divide that straight line.

To do this : Draw a perpendicular to LME which cuts Ox at m_1, and Oy at e_1; mark on it the point l_1 such that $\frac{l_1 m_1}{l_1 e_1} = \frac{LM}{LE}$; join Ol_1 which cuts $V_\lambda Z$ at V_L.
Draw through V_L, the perpendicular to LME which cuts Ox at V_M, and Oy at V_E.

OV_L, OV_M, OV_E are the velocities of L, M, E.
$V_\lambda V_L$ is the relative velocity of the link block.
Construct on OV_E a figure $V_E Og$ similar to EFG, such that OV_E corresponds to FE.
Og is the velocity of G.

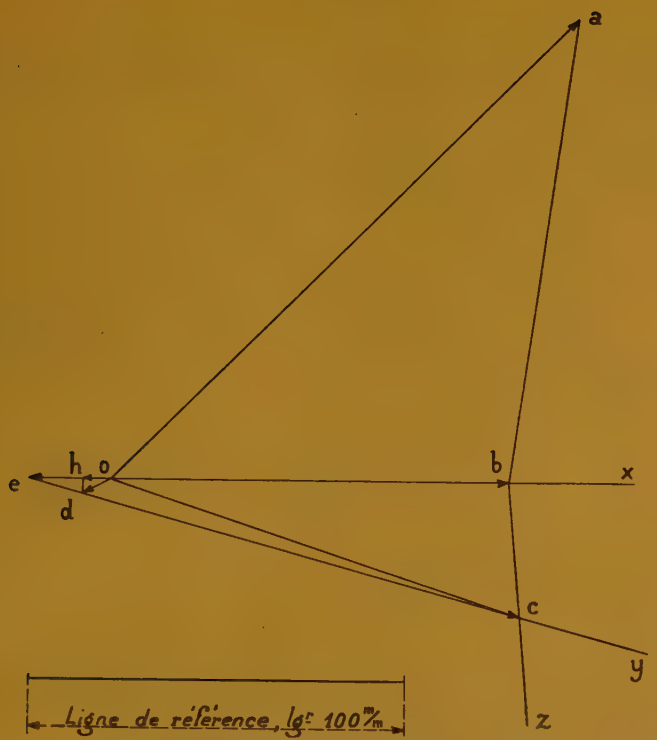


Fig. 26. — Velocities of the low pressure piston B, the combination lever CDE and the low pressure valve H. — Scale $\frac{1}{2\omega}$.

Reference line, length 100 mm.

Legend :

Draw *oa* equivalent to the velocity of the point A.

This velocity is parallel to the tangent at A of the circle swept out by the crank, and is directed forward in the sense of rotation. Its real magnitude is $\omega \times oA = \omega \times 350$.

Owing to the scale $\frac{1}{2\omega}$ of this figure, it is represented by the vector $\overline{oa}$ of length 175 mm.

Draw *ox* parallel to OB :

ab perpendicular to AB, wich cuts *ox* at *b*.

ob is the velocity of B.

Draw *oe* equivalent (with the exception of the scale , to OV_R of fig. 25 ;

ey perpendicular to EC ;

bz perpendicular to BC ; these two straight lines intersect at *c*.

oc is the velocity of C.

Mark on *ec* the point *d* such that $\frac{ed}{ec} = \frac{ED}{EC}$.

od is the velocity of D.

Draw trough *d* the perpendicular to DH ; it meets *ox* at *h*.

oh is the velocity of the valve H.

Fig. 27. — Velocity of the point E' of the transmission rod of the high pressure gear. — Scale $\frac{2}{\omega}$.

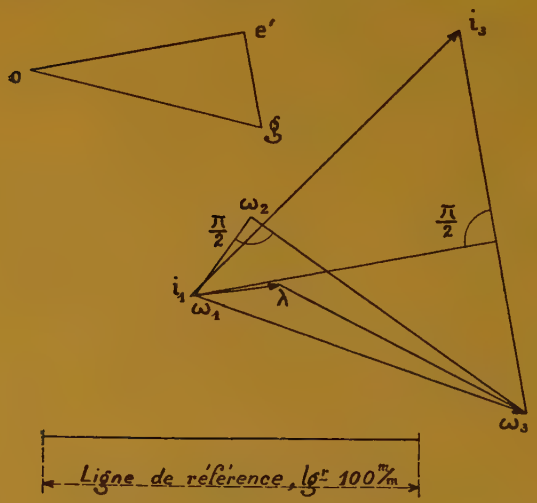


Fig. 28. — Accelerations of the points P and λ of the link.

Scale $\frac{1}{2\,\omega^2}$.

Figs. 27 and 28.

Legend of figure 27 :

Draw Og equivalent to Og of figure 25.

Draw through O the parallel to the tangent at E' to the circumference F'.
through g the perpendicular to E'G.
These two straight lines intersect at e'.

Oe' is the velocity of E'.

Legend of figure 28 :

Draw $i_1 i_3$ equivalent to the acceleration of I, directed along the radius, towards the centre and equal, on the scale $\frac{1}{n\ \omega\ 2'}$, to the nth of the real magnitude of the eccentric crank OI.

In this case, this magnitude being 200 mm. and the scale $\frac{1}{2\ \omega\ 2}$, we have $i_1 i_3 = 100$ mm.

Draw $i_1 \omega_1$ parallel to IP, in the same sense and equal to $\frac{\overline{ip}^2}{IP}$.

ip is measured on figure 24 ; on this figure on the scale $\frac{1}{2\,\omega}$, $ip = 24$ mm., therefore $ip = 48\ \omega$.

$\overline{ip}^2 = 2304\ \omega^2$. IP = 1150 mm, $\frac{\overline{ip}^2}{1\ P} = 2.03\ \omega^2$, which on the scale $\frac{1}{2\,\omega^2}$ of figure 28 is represented by 1.01 mm., $i_1 \omega_1 = 1$ mm.

Draw $\omega_1\omega_2$ parallel to PO_1, in the same sense and equal to $\frac{\overline{op}^2}{O_1 P_1}$.

op is measured on figure 24; on this figure, on the scale $\frac{1}{2\,\omega}$, $op = 81$ mm.; therefore $op = 162\,\omega$;

$\overline{op}^2 = 26\,244\,\omega^2$. $O_1P = 500$ mm., $\frac{\overline{op}^2}{O_1P} = 52.4\,\omega^2$, which, on the scale $\frac{1}{2\,\omega^2}$ of figure 28, is represented by 26.2 mm. $\omega_1\omega_2 = 26$ mm.

Draw trough ω_2 the perpendicnlar to $\omega_1\omega_2$;

trough i_3 the perpendicular to $i_1\omega_1$.

These two straight lines intersect at ω_3.

$\omega_1\omega_3$ is the accelaration of P.

Construct on $\omega_1\omega_3$ a triangle $\omega_1\omega_3\lambda$ similar to $O_1P\lambda$, such that $\omega_1\omega_3$ corresponds to O_1P.

$\omega_1\lambda$ is the acceleration of the point λ of the link.

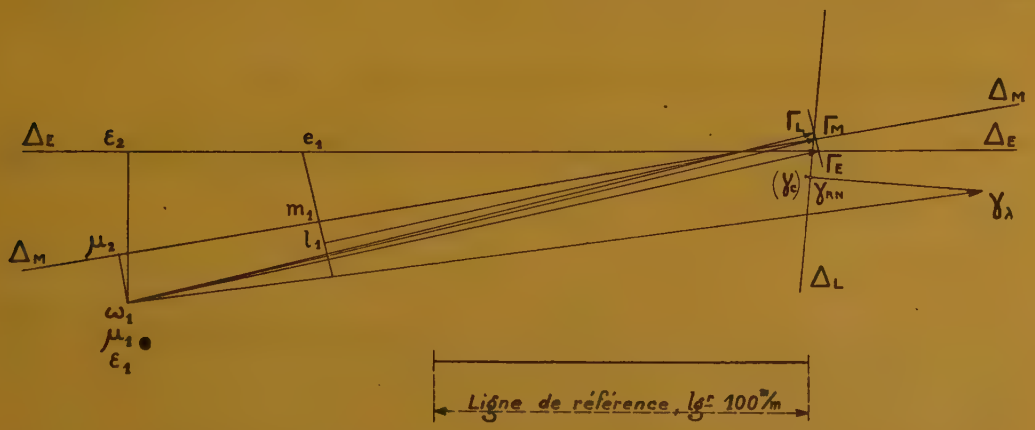


Fig. 29. — Acceleration of the points of the radius rod LME. — Scale $\frac{5}{\omega^2}$.

Legend ;

Draw $\overline{\omega_1\gamma\lambda}$ equivalent to $\overline{\omega_1\lambda}$ of figure 28; this is the driving acceleration.

The scale here employed being actually ten times as great as that of figure 28, the vector $\omega_1\gamma\lambda$ will be ten times as great as $\omega_1\lambda$.

Draw through γ, the perpendicular to $V_\lambda V_L$ of figure 25 in the sense OV_L of that figure.

Measure off on this perpendicular the vector $\gamma\gamma_c = 2\,\overline{V_\lambda V_L}\cdot\frac{op}{O_1P}$ (op taken from figure 24.)

This vector is the complementary acceleration.

On the scale $\frac{5}{\omega^2}$ of figure 2 ', $\gamma'_c\gamma_c$ is represented by 47 mm.

Draw through γ_c in the direction of the normal to the link and towards the centre, the vector $\gamma_c\gamma_{RN} = \frac{V_\lambda V_L^2}{R}$, R being the radius of the link.

This vector is the normal component of the acceleration of the relative movement of the link block.

On the scale $\frac{5}{\omega^2}$, $\gamma_c\gamma_{RN}$ is represented by a length of 0.66 mm.

Draw through γ_{RN} the perpendicular Δ_L to this last vector.

Measure off from ω_1 on the parallel to LME and, in the sense LME, the vector $\omega_1\mu = \frac{V_L V_M}{LM}$ ($V_L L_M$ taken from figure 25).

On the scale of the figure, the magnitude $\mu_1\mu_1$ is inappreciable, μ_1 practically coincides with ω_1.

Draw trough μ_1 the parallel to MN and measure off on it in the sense MN the vector $\mu_1\mu_2 = \frac{\overline{V_M}^2}{MN}$

$\mu_1\mu_2 = 13$ mm. on the scale $\frac{5}{\omega_2}$.

Draw through μ_2 the perpendicular Δ_M to $\mu_1\mu_2$.

Measure off from ω_1 on the parallel to LME and in the sense LME the vector $\omega_1\varepsilon_1 = \frac{\overline{V_L V_E}^2}{LE}$ ($V_L V_E$ taken from figure 25 .

ϵ_1 practically coincides with ω_1.

Draw through ε_1 the parallel to EF and measure off on it in the sense EF the vector $\varepsilon_1\varepsilon_2 = \frac{\overline{V_E}^2}{EF}$

$\varepsilon_1\varepsilon_2 = 40.2$ mm. on the scale $\frac{5}{\omega_2}$.

Draw through ε_2 the perpendicular Δ_E to $\varepsilon_1\varepsilon_2$

Determine, as already stated, figure 25, a perpendicular to LME divided by the three straight lines Δ_L Δ_M Δ_E at the points Γ_L Γ_M Γ_E in the same proportion as L, M, E.

The vectors $\omega\Gamma_L$; $\omega\Gamma_M$; $\omega\Gamma_E$ are the accelerations of the points L M E

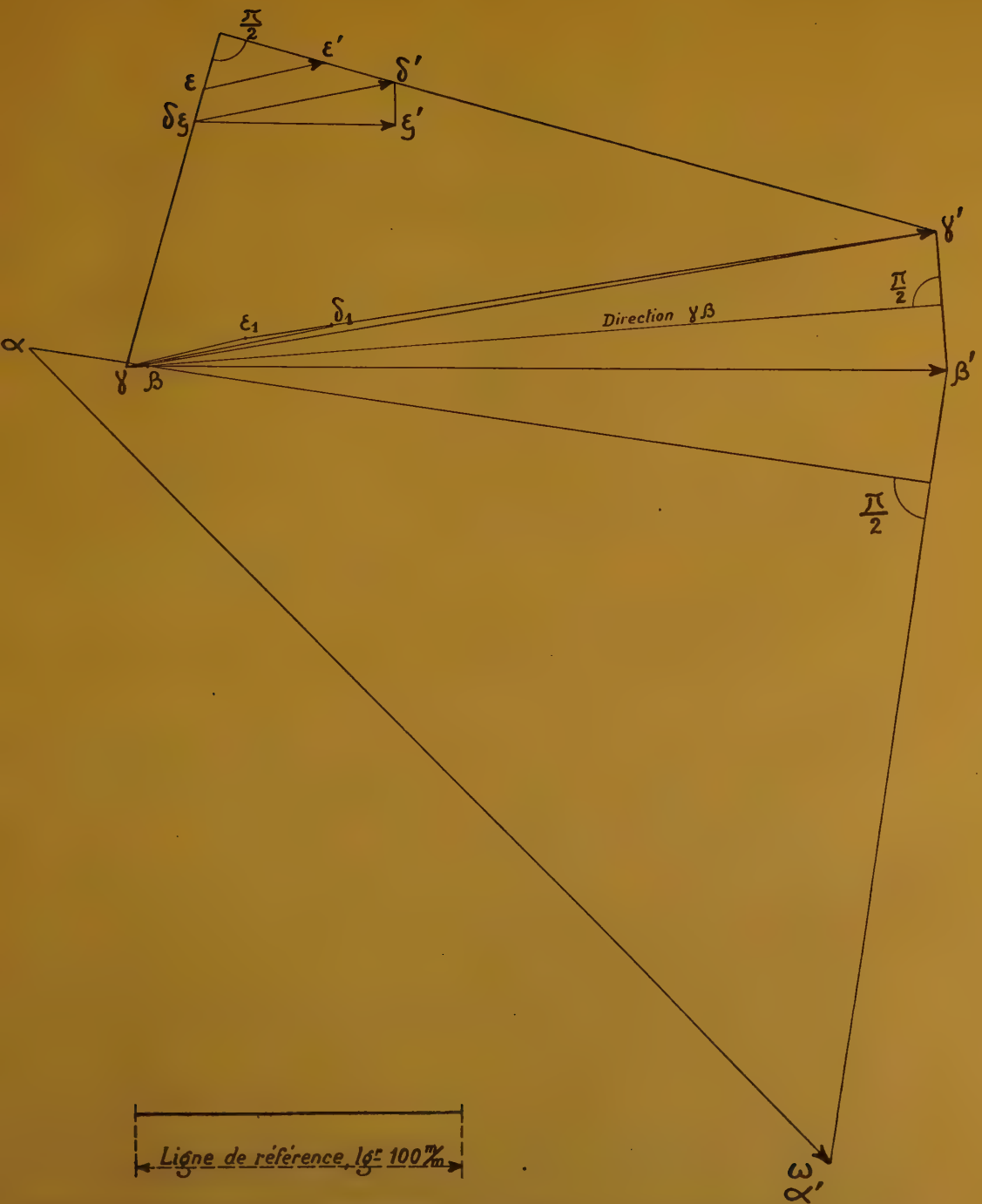


Fig. 30. — Accelerations of the low pressure piston B, the combination lever CDE and the low pressure valve H.

Scale $\frac{1}{\omega^2}$

Legend to figure 30 :

1. Acceleration of B.

Draw $\overline{\alpha\alpha'}$ equivalent to the acceleration of A : parallel to OA, in the same sense and equal on the scale $\frac{1}{\omega_2}$ to the real magnitude of OA.

This centripetal acceleration is equal to

$$\frac{(\omega \times \text{real magnitude of OA})^2}{\text{real magnitude of OA}} = \omega^2 OA, \text{ or on the scale } \frac{1}{\omega^2}, \ \overline{\alpha\alpha'} = OA = 350 \text{ mm.}$$

Draw $\overline{\alpha\beta}$ parallel to $\overline{AB}$ and equal to $\frac{\overline{ab}^2}{AB}$.

$\overline{ab}$ is represented on figure 26 on the scale $\frac{1}{2\omega}$ by 124 mm.

$\overline{ab} = 248$ mm. ; $\overline{ab}^2 = 61504$. $\qquad \frac{\overline{ab}^2}{AB} = \frac{61504}{1750} = 35$ mm.

Draw through β the parallel to OB and through α' the perpendicular to AB or $\alpha\beta$; these two straight lines intersect in β'.

$\beta\beta'$ is the acceleration of the point B

2. Acceleration of C

Draw $\overline{\beta\gamma}$ parallel to BC and equal to $\frac{\overline{bc}^2}{BC}$;

$\overline{\gamma\varepsilon}$ parallel to CE and equal to $\frac{\overline{ce}^2}{CE}$.

Mark off on $\gamma\varepsilon$ the point δ such that $\gamma\delta = \frac{\overline{cd}^2}{CD}$.

Draw through ε the vector $\overline{\varepsilon\varepsilon'}$ equivalent (with the exception of the scale) to the vector $\omega_1 \Gamma_E$ of figure 29.

Draw through β' the perpendicular to $\beta\gamma$ and through ε' the perpendicular to $\gamma\varepsilon$; these two straight lines intersect at γ'.

$\overline{\gamma\gamma'}$ is the acceleration of the point C.

3. Acceleration of D.

Through γ draw $\overline{\gamma\varepsilon_1}$ equivalent to $\overline{\varepsilon\varepsilon'}$; join $\varepsilon_1\gamma'$ and mark on it the point δ_1 which divides $\varepsilon_1\gamma'$ in the ratio $\frac{ED}{EC}$; join $\gamma\delta_1$.

$\gamma\delta'$ is the acceleration of D.

As a check, if the vector $\overline{\delta\delta'}$ equivalent to $\overline{\gamma\delta_1}$ is drawn through δ, δ should fall on $\gamma'\varepsilon'$.

4. Acceleration of H.

Draw $\overline{\delta\xi}$ parallel to DH, in the same sense and equal to $\frac{\overline{dh}^2}{DH}$. (The point ξ coincides with the point δ.

Draw through ξ the parallel to the valve axis HX and through δ' the perpendicular to $\delta\xi$, that is to say to DH ; these two straight lines intersect in ξ'.

$\overline{\xi\xi'}$ is the acceleration of H

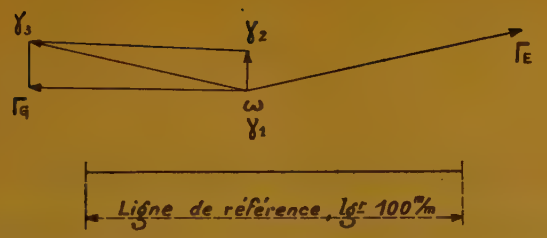


Fig. 31. — Accelerations of the ends of the transmission rod GE'. — Scale $\frac{2}{\omega^2}$.

Legend :

Construct on a vector $\overline{\omega\Gamma_E}$ equivalent to that of figure 29, a figure $\Gamma_E\omega\Gamma_G$ similar to the bent lever EEG.

$\omega\Gamma_G$ is the acceleration of the point G.

Draw through ω the vector $\omega\gamma_1$ parallel to GE', in the same sense and equal to $\frac{\overline{ge'}^2}{GE'}$.

(ge' taken on the scale in figure 27).

In this case, the point γ_1 practically coincides with ω.

Draw through γ_1 the vector $\gamma_1\gamma_2$ parallel to E'F', in the same sense and equal to $\frac{\overline{oe'}^2}{E'F'}$.

(oe' taken on the scale in figure 27.)

Draw through γ_2 the perpendicular to E'F' and through Γ_G the perpendicular to E'G. These two straight lines intersect at γ_3.

$\gamma_1\gamma_3$ is the acceleration of the point E'.

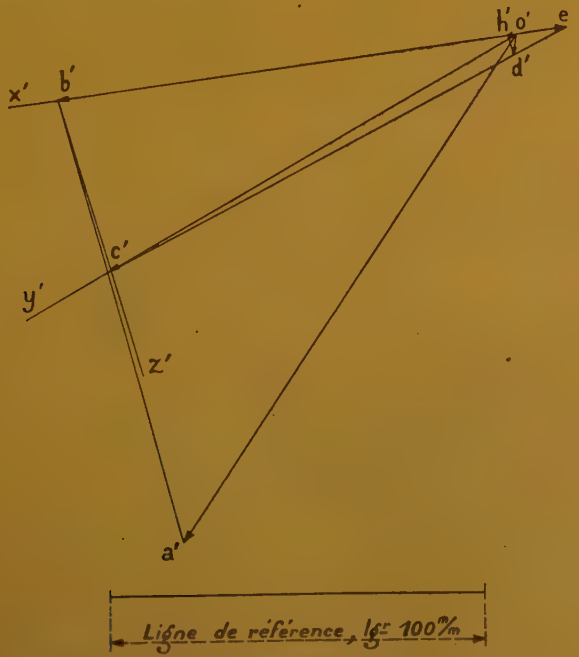


Fig. 32. — Velocities of the high pressure piston B', the combination lever C'D'E' and the high pressure valve H'.

Scale $\frac{1}{2\omega}$.

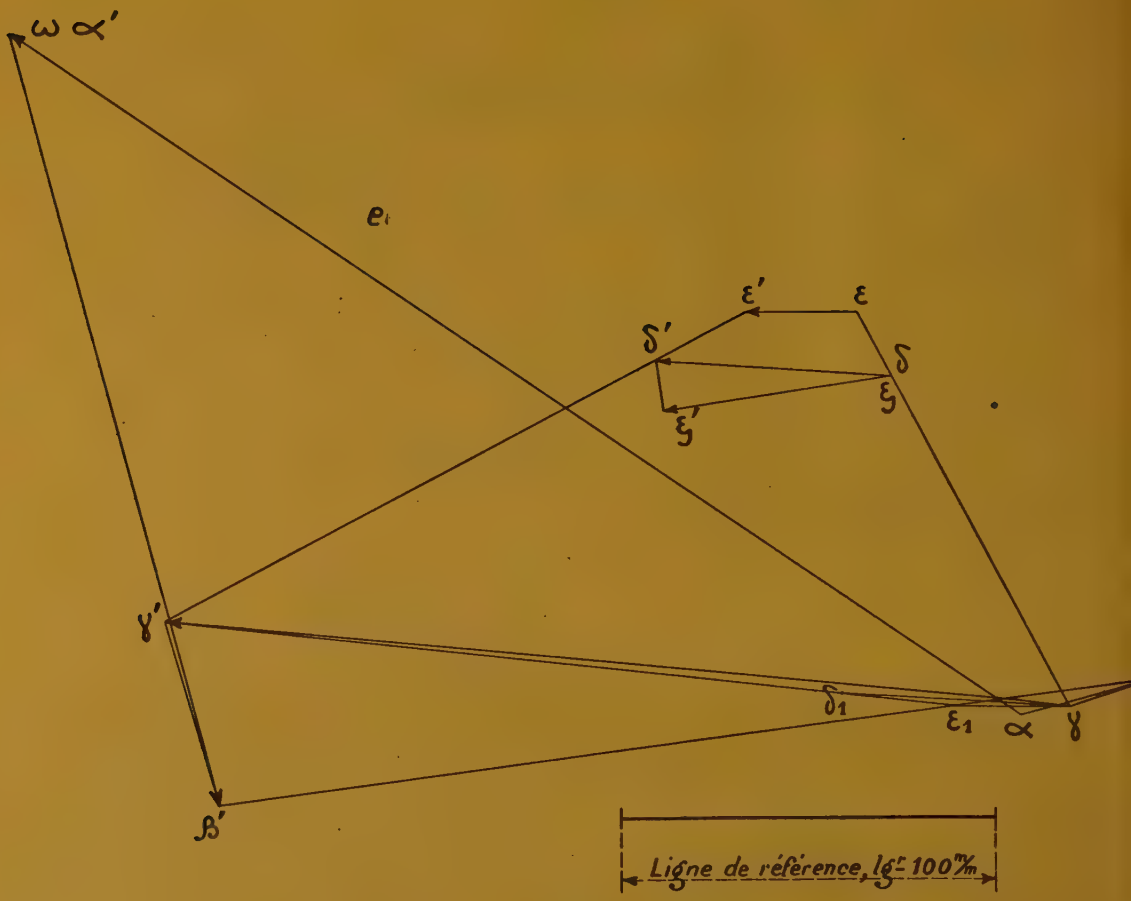


Fig. 33. — Accelerations of the high pressure piston B', the combination lever C'D'E' and the high pressure valve H'. — Scale $\frac{1}{\omega^2}$.

Legend to figures 32 and 33 :

The constructions are the same as for the low pressure.

[625.14 & 721.9.]

Note on a method of fixing the track on a rigid, continuous and adjustable reinforced concrete platform, (1)

by V. FORESTIER,
Consulting Engineer, Paris.

Fig. pp. 764 and 765.

FIRST PART.

Historical review and experiments.

General considerations. — Although the steady increase in traffic on the railways has necessitated the placing in service of ever heavier vehicles, travelling at ever increasing speeds, the practice of placing the track on sleepers and ballast has remained approximately the same since the start of this transport industry. In this fact it is necessary that one should see the effect of an evolution which, although rapid, has nevertheless been brought about progressively, without any sudden development having required a complete transformation of the permanent way. But it is quite certain that if railway permanent way had to be designed afresh, other methods of construction would be preferred to the present one which consists of using separate transverse units to distribute on the ground the heavy loads which move in a longitudinal direction over the track. In effect, in a track set on sleepers and ballast, the longitudinal resistance is furnished solely by the rails, which, in spite of the heavy section which has been given them on account of this fact, only possess a comparatively small moment of inertia having regard to the masses moving on them; the consequence is that safety can only be assured by regular and careful maintenance and frequent verifications. These operations which weigh heavily on the budgets of the Companies and are becoming more and more difficult to perform and to control, will become insufficient in the near future, assuming a steady increase in traffic which will necessitate before long further increases in loads and speeds.

The present time then seems opportune to envisage the permanent way problem in quite another manner, abandoning the idea which has prevailed up to now of improving the existing methods, and to search for a more rational solution which modern materials can procure.

The idea of a rigid platform. — Messrs. Frank Alfred, General Manager, and Paul Chipman, Engineer, in charge of research to the Pere Marquette Railroad in the United States, made the following observation several years ago: « If a State finds it economic to replace good macadam roads by permanent concrete ones for motor cars, lorries and buses at a cost of 50 000 dollars per mile, why cannot railways find a pecuniary advantage in doing the same thing for their infinitely greater tonnage ? It ought to be

(1) Translated from the French.

possible to construct a track which would require practically no other expenses other than the renewal of the rails. »

This was, it is believed, the first idea of a track fixed to a platform and we shall see later the experiments which followed. In France the idea has been taken up by Mr. Cambournac, Chief Engineer of the Nord Railway, who has also instituted a series of tests which will be mentioned later. Finally, quite recently, on 28 November 1930, at the meeting of the French Society of Civil Engineers, Mr. Bacqueyrisse, General Manager of the Société des Transports en commun de la Région Parisienne, spoke as follows :

« My opinion is that the existing method of supporting the tracks, which is moreover that adopted when railways were first built, no longer meets present day requirements. To have heavy loads travelling at high speeds on a track which moves, for that on ballast is constantly moving, does not seem to me to procure the maximum condition of safety. I visualise this condition in rigid supports, having rails anchored to a concrete plaform, the rails themselves having the greater part of their section embedded in a weak concrete so that they may be removed for repairs and renewals and finally all the joints welded.

Tests with rigid plaforms. — In the United States, the Pere Marquette Railroad constructed in 1926, near to Detroit, a trial section of double-line track 400 m. (1 300 feet) long, having a concrete platform. The principal object of this experiment was to solve the problem as to whether a rigid road was practical or otherwise from the point of view of the rolling stock; also great rigidity was obtained by a slab of concrete 18 inches thick and 10 feet wide for each road; in this slab were embedded two strong metal joists with trellis webs arranged longitudinally, whose upper flanges projecting through the concrete were utilised for fixing the rails. These joists were tied at intervals of 12 feet by transverse stays also consisting of open web joists. No disintegration of the concrete nor abnormal wear has been noticed, but on the other hand there is great smoothness in running.

In France, on the Nord System, Mr. Cambournac has carried out tests by embedding the rails in concrete cast in grooves in a slab of reinforced concrete. At the carriage washing shops at Landy, a section of track has also been fixed on a concrete platform, the rails being welded and embedded. At the Aulnoye depot the rails in the locomotive shed, originally fixed on longitudinal timbers, have been embedded in beams of reinforced concrete. So far the results of these experiments have been equally satisfactory as regards the concreting-in of the welded rails over a considerable length of track.

Advantages of a rigid continuous platform. — A road made solid by means of a ferro-concrete raft possesses, in addition to pecuniary advantages which will be referred to later, the following technical improvements over a road on sleepers and ballast :

1. The distribution of the loads is made over the whole surface of the platform, in such a manner that under the passage of the heaviest axles, the bearing pressure on the ground is of the order of 0.5 to 0.6 kgr. per cm^2 (7.1 to 8.5 lb. per sq. inch) instead of 2 to 3 kgr. (28 to 42 lb. per sq. inch).

2. Stability is greater due to the raft offering a greater resistance in every direction.

3. The rails no longer act as beams between the sleepers, their function being reduced to that of a rolling surface.

4. The concreted platform ensures protection to the track from damage caused to ballast by storms and floods.

5. It removes the lateral obstacles constitued by sleepers which aggravate the effects of derailments.

SECOND PART.

Description of a platform allowing easy lifting of the track.

Principle of the system. — The experiments described above have shewn that a rigid track is perfectly practicable and that it is possible to envisage sinking the rails in concrete so as to avoid the use of bolts, coach-screws, sole plates, clips, and consequently the bulk of maintenance costs.

But another problem remained to be solved, namely, that of lifting the track and adjusting the level of the rails. The pressure imposed on the ground being one quarter that caused by the sleepers and not exceeding 0.6 kgr. per cm² (8.5 lb. per square inch), it is certain that settlements will be small especially when existing formations are under consideration, but it is no less essential to have available at all times the means of rectifying the level of the rails and even the alignment of the track without the necessity of undertaking earthwork operations which interfere with traffic movements and disturb the homogeneousness of the sub-soil.

These requirements are met by the platform which is now to be described.

It consists essentially of two parts, the one resting on the top of the other, the lower one is formed of ordinary mass concrete or by the ground itself if of a sufficiently solid nature or already consolidated, when it will suffice to prepare the surface. The upper part consists of a ferro-concrete raft capable of adjustment by means of jacks resting on the fixed part; between these two parts there is interposed a layer of incompressible sand, the object of which is to minimise the effects of an excessive rigidity.

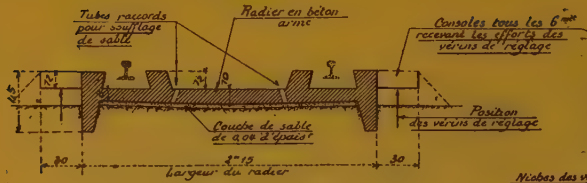
General arrangement and details. — The drawings illustrating the present article, shew the general arrangement and the details of the design which is proposed. It will be enough here to outline the principal features.

a) *Distribution of rolling loads.* — The rails are anchored between the longitudinal beams of a foundation raft of ferro-concrete calculated to spread the rolling loads uniformly over the whole area of the platform which is thus submitted to a pressure of only 0.6 kgr. per cm² under the axles of locomotives of the train type contemplated by the French Ministry Regulations.

b) *Lifting of the track.* — The longitudinal beams of the raft are provided at 6-m. (19 ft.-8 in.) intervals with brackets or lugs designed, as is also the raft itself, so that the whole may be supported by jacks placed under these projections. When it is required to lift the track, the jacks are put in place under the lugs and a progressive lifting is carried out operating upon the longest section of track possible. As this lifting proceeds, sand is injected under pressure into the space left under the raft so as constantly to maintain contact between it and the ground. Thus, the running of trains may be main-

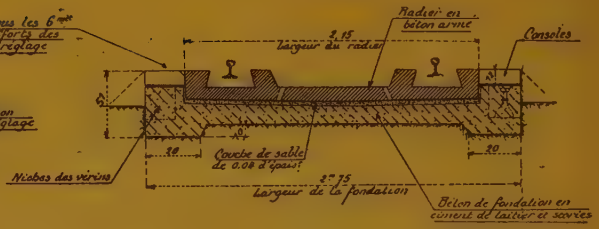
1. Track laid on good ground or on an already existing formation.

Cross section.

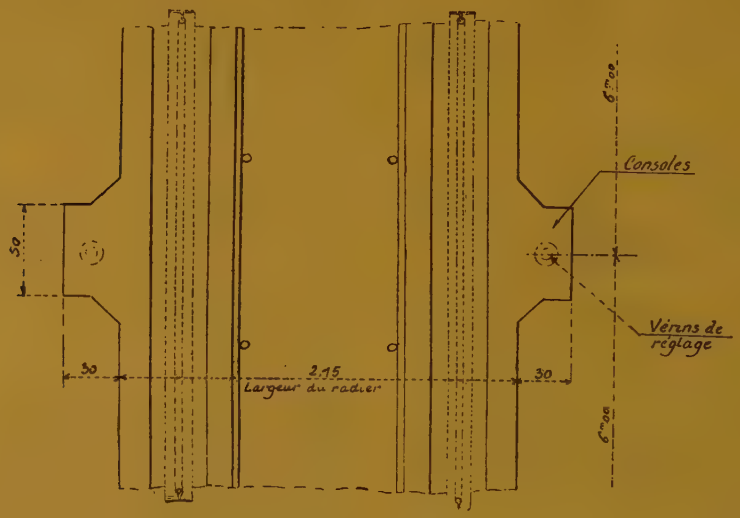

Tubes raccords pour soufflage de sable
Radier en béton armé
Consoles tous les 6 m. recevant les efforts des vérins de réglage
Position des vérins de réglage
Couche de sable de 0,04 d'épaisseur
0.30
2.15
Largeur du radier
0.30

2. Track laid on a new embankment.

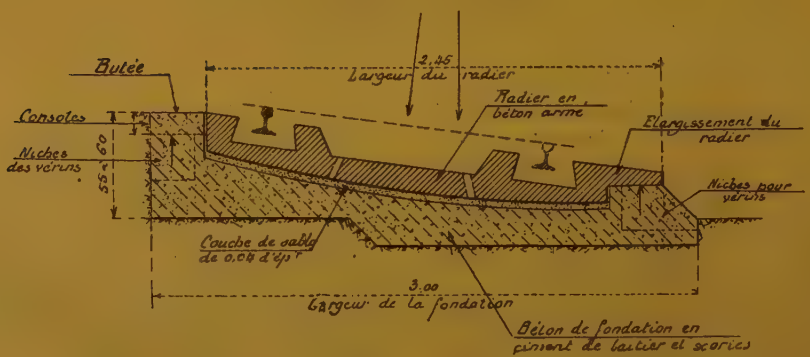
Cross section.



Plan.



3. Track laid on the cant.



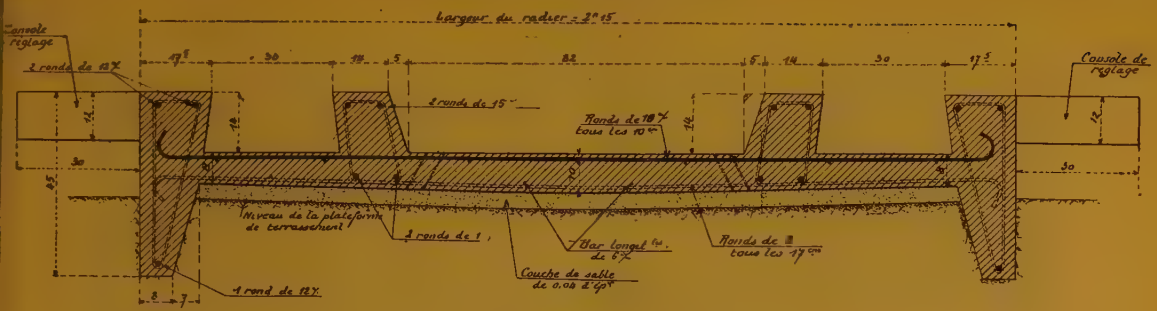
Explanation

Radier en béton armé = Ferro-concrete raft. — Tubes raccords pour soufflage de sable = Holes for the injection of sand. — Couche de sable de 0 m. 04 d'épaisseur = Layer of sand (1 9/16 inch) thick. — Largeur du radier = Width of the raft. — Consoles tous les 6 m. recevant les efforts des vérins de réglage = Brackets (19 ft. 8 1/4 in.) apart for taking the thrust of the adjusting jacks. — Position des vérins de réglage = Position of the adjusting jacks. — Consoles = Brackets. — Niches des vérins = Recesses for jacks. — Butée = Thrust block. — Béton de fondation en ciment de laitier et scories = Mass concrete of clinker, cement and slag. — Largeur de la fondation = Width of the

st, for supporting railway permanent way.

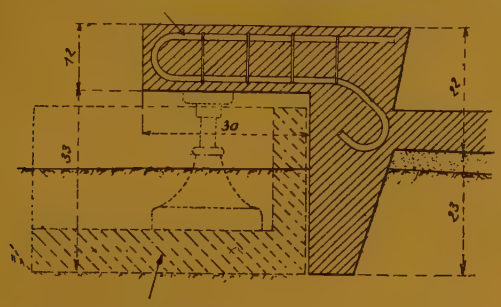
Details of construction.

Cross section of a running track.


Largeur du radier = 2m 15
Console de réglage
2 ronds de 12 %
2 ronds de 15
Ronds de 10 % tous les 10 cm
Niveau de la plateforme de terrassement
4 ronds de 1
Bar longit.ux de 6 %
Ronds de 8 tous les 17 cm
Couche de sable de 0.05 d'ép.
4 rond de 12 %

Section through brackets for taking the thrust of the adjusting jacks.

6 bars 12 mm. (1/2 inch.) dia. in each bracket.

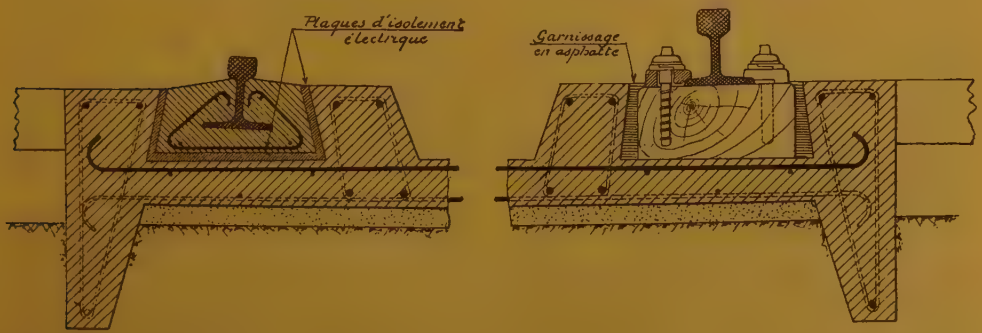


Ferro-concrete pad to be placed under the brackets when the track is adjusted.

Methods of fixing the rails.

1. *By embedding in ferro-concrete longitudinal sleepers.*

2. *On longitudinal timbers.*



terms :

foundation. — Vérins de réglage = Adjusting jacks. — Elargissement du radier = Widening of the raft. — Console de réglage = Adjusting bracket. — 2 ronds de 12 mm. = 2 bars 15/32 inch diam. — 2 ronds de 15 mm. = 2 bars 5/8 inch diam. — Ronds de 10 mm. tous les 10 cm. = Bars 3/8 inch diam. every 4 inches. — Ronds de 8 mm. tous les 17 cm. = Bars 5/16 inch diam. every 6 11/16 inches.— Barres longitudinales de 6 mm. = Longitudinal bars 1/4 inch diam. — Niveau de la plateforme = Formation level. — Plaques d'isolement électrique = Plates for electrical insulation. — Garnissage en asphalte = Asphalte filling.

tained between two successive liftings by the jacks and the adjustment of the level of the rails can be carried out with the greatest precision.

c) *Track resting on good ground or on ground already consolidated.* — In the case of a track substituted for one previously existing where the ground has already supported loads from sleepers for many years, as in the case of a new track laid on solid ground, it is enough to cover the surface with a layer of weak concrete and to spread thereon a layer of sand of 4 to 5 cm. (1 1/2 to 2 inches) thick to form the bearing surface for the ferro-concrete raft. The longitudinal beams are sunk about 20 cm. (8 inches) into the ground in order to avoid any lateral slipping and also to enclose the sand introduced at the moment of lifting the track.

d) *Track on a new embankment or non-resistant ground.* — In this case it will be wise to allow for a foundation of 15 to 18 cm. (6 to 7 1/4 inches) thickness of slag concrete made with blast furnace cement with the object of reinforcing and widening the bearing surface; recesses are then left for the brackets and they will serve to house the jacks at the time when the lifting of the track will be necessary. Lateral resistance is obtained by the edges of this foundation which are raised to the level of the underside of the brackets or lugs.

e) *Track with super-elevation.* — The arrangement is similar to that just described, but the reinforced raft has been widened on the side of the inner rail of the curve, whilst a strong thrust block has been provided on the side of the outer rail by the raised edges of the foundation slab. The upper face of the latter is of a concave profile in order to obtain a better distribution of the loads, whatever may be the speed of the trains. It will always be easy moreover, by increasing the section and the armouring of the beams of the concrete raft, to strentghen those parts of the track, which for any reason, would be more particularly subjected to exceptional strains.

f) *Fixing of the rails.* — The drawings shew two methods of fixing the rails, one by embedding them in concrete filling, the other by attaching them to timber longitudinals recessed in a ferro-concrete raft.

The first solution consists of sinking the rails to the lower side of their heads in concrete filling plain or reinforced, cast in the spaces reserved for this purpose between the longitudinal beams of the raft. This arrangement puts the rails almost completely under shelter from atmospheric influences so that the expansion joints could be spaced at greater intervals, especially as the welding of the rails has less importance, since they no longer work in bending and their rupture would not bring about serious consequences. In districts where electrical insulation is necessary, plates of compressed cork, rubbered felt, or similar imperishable insulating material, capable of resisting heavy compression and adhering perfectly to the concrete will be interposed between the ferro-concrete of the raft and the filling concrete.

The second solution consists of fixing the rails to longitudinal timbers sunk in suitably shaped housings in the concrete raft, the rail fastenings being coach screws and clips as normally employed for timber sleepers; these may be uniformly spaced at 20 to 25 cm. (8 to 10 inches) and staggered so as to secure the rails along their entire length. The timbers are adequately protected from at-

mospheric influences, being nowhere in contact with the ground and having only a small exposed surface.

Initial cost and economic advantages. — The prime cost of a road on a ferro-concrete raft naturally depends on the conditions under which the work is carried out and the prices of the materials. However, as an example, assuming cement costs 280 francs per ton, sand 55 francs per cubic metre and gravel 70 francs per cubic metre, which are average prices, the initial cost would be of the order of 250 francs per lineal metre, *i. e.* 96.25 fr. per foot, (exclusive of rails), it also being assumed that the work would be carried out by gangs belonging to the railroad and allowing for the addition of 15 % overhead charges. For places requiring a mass concrete foundation, (roads on gradients or weak ground), the necessary increment would vary between 55 and 75 fr. per lineal metre (18.78 and 22.88 fr. per foot) of track. Now an ordinary road carried on timber sleepers requires roughly 1.7 cubic metres of ballast, 1 1/2 sleepers and 20 kilogrammes of steel for sole plates, clips, bolts, coach screws, anti-creep devices and tie plates between the sleepers; the cost of these materials when placed in position is of the order of 240 to 260 francs per lineal metre (73.20 and 79.30 fr. per foot) of track.

The adoption of a road on a raft of ferro-concrete, capable of being lifted and adjusted easily without any earthworks and without interfering with traffic does not therefore entail a greater initial outlay than in the case of a road on sleepers and ballast. It is less than that necessitated by the use of ferro-concrete or steel sleepers. Eventually considerable economies would be realised each year by reason of the following considerations.

1. The cost of maintenance and renewal of ballast would be eliminated as well as that of weeding.

2. The rails would have a longer life and their weight might be reduced as a result of the removal of bending and shearing stresses.

3. The maintenance costs of both rolling stock and permanent way would be diminished on account of greater smoothness of running and reduced bearing pressure on the ground.

4. The reduced risks of accidents and sabotage and the consequences arising therefrom.

Method of carrying out the work. — When the construction of a new line is concerned, the building of a ferro-concrete raft would be carried out in the first instance without any difficulty as the earthworks would be prepared for this purpose. On the other hand, if it is a question of a line already under traffic, the removal of the old track and the substitution of the new one are operations which could be performed in a few hours. In this case the ferro-concrete rafts would be pre-cast at depots specially equipped for the purpose, and in sections or 12 to 24 m. (39 ft. 4 1/2 in. to 78 ft. 9 in.) in length corresponding to the lengths of rails to be used. These sections, placed in a depot near to their ultimate destination, will be transported thither on specially designed wagons to enable 200 to 250 m. (656 to 820 feet) of track to be laid in a few hours. It is proposed to give in a future note particulars of the organisation of the depots where the sections are manufactured and of the equipment for placing them in the road.

[621 .33 (.45)]

Railway electrification in Italy.

Figs. 1 to 9, pp. 770 to 780.

(*Modern Transport.*)

The electrification of the Italian railways actually began in 1897, in which year it was decided to carry out a series of experiments with accumulator traction, the 650-volt d.c. third-rail system, and the 3 000-volt 15-cycle 3-phase system. Experiments on these lines were continued during the succeeding years until 1905, when another epoch was opened owing to the principal railways being taken over by the State. Subsequently, between 1910 and 1916, some 230 miles of line were electrified on the 3-phase system at 16 2/3 cycles. Owing to this system requiring special generating stations, further electrification schemes were carried out on the 3-phase system at the industrial frequency (45 cycles), and with 3 000 volts (d.c.), this system having the advantages of simplicity of the overhead contact line and ease of speed regulation. The second period in the history of railway electrification in Italy dated from 1905 to 1920, while the inauguration of the present phase followed immediately after. Certain of the details which follow were given by Signor G. Bianchi (1), chief inspector, rolling stock and running, Italian State Railways, in a paper read before the Institution of Electrical Engineers, London (an abstract of which was published in the 22 November 1930, issue of *Modern Transport*), while the remainder is abstracted from documents furnished by the administration of the Italian State Railways.

(1) Reporter on Question VII (Electric locomotives for main line traction) discussed at the Madrid Session (1930) of the International Railway Congress Association.

Essential requirements.

The experience gained since 1920 has enabled many most important conclusions to be arrived at, and the question of the advisability of carrying out further electrification on the 3-phase system has been warmly debated. Finally, the following requirements were recognised as essential when considering the choice of the system to be adopted for a large programme of electrification :

For level lines (in particular for the new line between Bologna and Florence and between Rome and Naples) a speed of 65 m. p. h. ought to be easily reached and be capable of slight regulation either up or down.

In order to employ in the best way the hydraulic power which is so plentiful in Italy, it has been recognised that it is desirable, from both the technical and the economic points of view, that the electric power for traction purposes should have, as far as possible, the same frequency as that intended for other industrial purposes, and that there should be the possibility of using the same transmission lines as those for the industrial supply.

As is shown elsewhere, the consumption of electric power for railway traction service is, in fact, very small when compared with the total consumption of other industries, so that, as regards the economy of electrification, it is very important to be able to use the existing

TABLE 1. — **Lines operated electrically in 1930.**

ROUTE.	Date of electrification.	Length in miles of			
		Single track.	Double track.	Route.	Electrified track.
Milan-Varese, Porto-Ceresio	1901	8.7	36	44.7	91 (*a*)
Locco-Colico, Sondrio and Colico-Chiavenna	1902	65	—	65	77 (*b*)
Genoa-Ronco	1911-15	—	38	38	106 (*c*)
Turin-Modane	1912-20	20	49	69	166 (*e*)
Savona-Ceva	1914	28	—	28	48 (*c*)
Lecco-Monza	1914	19	3.7	22.7	40 (*e*)
Sampierdarena-Savona	1916	25	—	25	39 (*c*)
Torino-Torrepellice, Troffarello-Chieri, Bricherasio-Barge	1917-21	—	—	61.3	48.8 (*c*)
Turin-Ronco-Tortona-Novi-Alessandria-Voghera	1922-24	—	151.6	151.6	403 (*c*)
Lines of Genoa Harbour	1926	14	—	14	20 (*c*)
Genoa-Leghorn	1926	25	95	120	270 (*c*)
Bologna-Florence	1927	57	24	81	153 (*c*)
Naples-Villa Literno	1927	—	22	22	36 (*a*)
Foggia-Benevento	1927	57	5.4	62.4	87 (*d*)
Rome-Sulmona	1928	108	—	108	150 (*e*)
S. Pierdarena-Ovada-Alessandria	1929	40	5.8	45.8	60 (*c*)
Bolzano-Brennero	1929	—	55	55	141 (*c*)
			Total	1013.5	

System employed : (*a*) d.c. (650 V.); (*b*) 3-phase (3300 V., 15-cycles); (*c*) 3-phase (3700 V., 16 2/3 cycles); (*d*) d.c. (3000 V.); (*e*) 3-phase (10 000 V., 45 cycles).

installations for generation and transmission of power. The two requirements mentioned above led to the decision to test two other systems of electrification, viz., 3-phase current at industrial frequency (10 000 volts, 45 cycles), and high-tension (3 000 volts) direct current. The 3-phase system at industrial frequency is now being tested on the Rome-Sulmona line. This system, which is referred to below, satisfies only the second requirement, the difficulty first mentioned still remaining.

The system adopted.

The 3 000-volt d.c. system has been adopted on the Benevento-Foggia line, which has now been in operation for more than three years. The good results obtained, and the fact that both the desiderata mentioned are satisfied, make it certain that this system will be adopted on other lines. When, in 1919, the test of these two new systems was decided upon, many persons pointed out the difficulties which would arise from the fact that it was impossible for the locomotives of one type to run on the lines electrified on the other system. In order to avoid this difficulty it was then decided that each system should be limited to its own zone. It was accordingly decided that in Northern Italy the old 3-phase, 16-cycle system should be continued. The Central Italy zone, in the event of the test at industrial frequency being a success, would be electrified on this system, whilst in Southern Italy the d.c. system would be adopted. It is important to note that locomotives equipped for 10 000 volts and industrial frequency can run at a reduced speed (about one-third of their normal speed) on branches electrified on the 3 700-volt, 16-cycle system. The

railway stations at the junction of the two systems might, therefore, be electrified on the 16-cycle system, so that access to these stations would also be assured to locomotives equipped for the industrial frequency. On the other hand, the question of the possibility of running d.c. locomotives on the 3-phase system

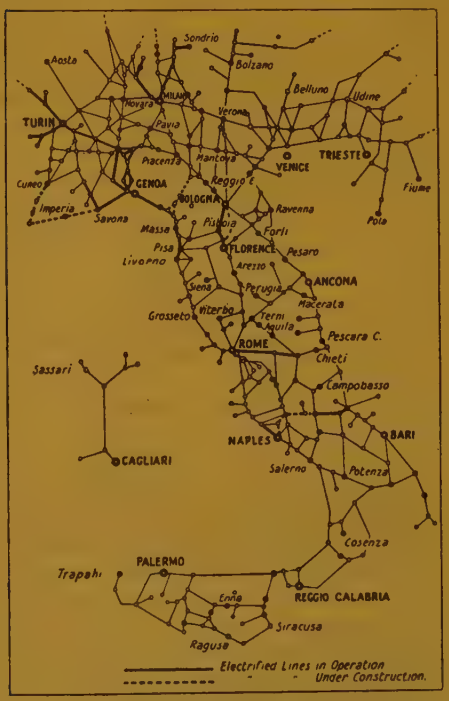


Fig. 1. — Sketch map of the Italian railway system showing electrified lines in operation and under construction.

lines has not yet been completely investigated. However, with careful choice of the limits reserved to each system, it is possible to reduce to the minimum the necessity for a locomotive of one system to run on the lines of another.

Present state of electrification.

The lines now operating electrically are shown on the sketch map (fig. 1), by a thick line, and also in table 1. On the 1 013 miles now in operation, last year's traffic was about 6 800 million ton-miles, which represents about 20 % of the total traffic on the 10 500 miles of railway track belonging to the State Railways. The train-miles operated in a year exceed thirteen million. The average hauled weight of these trains is 300 tons, while for the lines operated with steam locomotives it is 250 tons. It is interesting to remark that the electrified lines, besides experiencing heavier traffic, have also the steepest gradients and the greatest operating difficulties. The Genoa-Ronco line already mentioned, for instance, has the maximum admissible gradient for a main line with heavy traffic (1 in 28) and an increasing traffic, which may reach 3 000 cars per day, coming up from Genoa harbour. The Turin-Modane line crosses the Alps Chain under Mont-Cenis, and the Bolzano-Brennero line crosses one of the highest Alpine passes (4 300 feet above sea level), while the line now operating between Bologna and Florence crosses the Apennines with gradients that reach 2.6 % (1 in 38), and has more than forty tunnels and a very heavy traffic. Although these conditions are favourable from the point of view of the economical results of electric traction, they cause electric traction to be more difficult than steam traction. It is obvious that the operating regularity of a line might be expected to be worse with electric than with steam locomotives, owing to the greater number of factors on which the operating regularity depends. Experience has, nevertheless, proved in Italy that in some instances the operating regularity on the electric lines is as good as that on the steam lines.

Lines now being electrified.

In addition to the lines mentioned, there are now in course of electrification the Savona-Ventimiglia and Cuneo-Ven-

timiglia lines (130 miles in length; 3-phase system), and the Naples-Benevento line (60 miles in length; 3 000 volts d.c. system). The new lines between Rome and Naples (134 miles) and Bologna and Florence (62 miles) are also to be electrified (see table 2). These two lines have been recently constructed in order to assure easier and quicker communication between north and south Italy, and they represent remarkable examples of railway engineering. Both lines are to be electrified with d.c. at 3 000 volts, a system which, as

TABLE 2. — **Lines now in course of electrification.**

ROUTE.	Date of electric operation.	Length in miles of			System.
		Double track.	Single track.	Route.	
Cuneo-Ventimiglia	1931-32	62	—	62	3-phase (3 700 V.) 16 2/3 cycles d.c. (3 000 V.)
Savona-Ventimiglia	1931-32	65	3	68	
Vezzano-Fornovo	1932	48	11	59	
Benevento-Naples	1932	48	12	60	
Bologna-Florence (new line)	1933	—	60	60	
			Total	309	

stated, has been recognised as the most suitable for high-speed traffic. As a result of this decision, the 3 000-volt d.c. system will not remain restricted to the lines of Southern Italy, as was originally intended. In fact, as it has recently been decided to electrify also the new Bologna-Florence line on this system, it may be necessary to carry out the electrification of the Florence-Rome and of the Milan-Bologna lines on the same system. When these works have been accomplished there will extend from Milan to Naples a line which, traversing the peninsula from north to south, will carry the greatest part of the longitudinal traffic of the Italian railways. The three-phase system will probably be limited to the Piedmont and Liguria section and, for some time to come, to some isolated lines such as the Monza-Lecco and the Bolzano-Brennero. It is evident that at some time in the future it will become necessary to study the co-ordination of lines operated on the three-phase and d.c. systems. To achieve this it will perhaps be necessary to convert the system of some lines from three-phase to d.c. current and to investigate in every detail the methods of operation (only partially studied at present) in those stations which will remain on the border-line of three-phase and d.c. systems.

Economic considerations.

The coal resources of Italy are so poor that it may be said that the whole of the coal consumed is imported. The coal imported in Italy in 1929 was about 12 500 000 tons. Of this quantity, about 2 700 000 tons have been consumed in the operation of the 10 500 miles of the State railways. The price of coal in Italy since the war has been subject to large fluctuation, having reached £5 per ton immediately after the war, when Italy's allies had to consider their own requirements first. At the present time the cost per ton, placed on tender, is about £1 10 s. The scarcity of coal in Italy is, however, largely compensated by the abundance of hydraulic resources. In 1929 about 10 thousand million kw.-h. were produced by hydraulic power plants, the average developed power of which now exceeds 2 million

Fig. 2. — The hydro-electric power station at Sagittario, on the Rome-Sulmona line.

kw. One of the objects of electrification is to reduce the importation of coal by utilising natural supplies of energy. The electrification of the lines now in operation has resulted in a reduction of coal imports by more than 580 000 tons, by the substitution of 347 million kw.-h. of electrical energy.

Installation and operating expenses.

As regards installation and operating expenses, the following figures, largely approximate, may be given. The cost of construction of the e.h.t. transmission lines, substation buildings and machinery, contact lines, telephone installations necessary for the electric service, modifications of signalling and block installations and moving of telegraphic lines which are near the electric lines, modification of the station lighting installations, all work required in tunnels for installing the electric equipment, and finally for the equipment of running sheds for electric locomotives, amounts to some £6 500 a mile for single-track lines and to about £10 000 a mile for double-track lines. With the normal density of traffic and frequency of trains it is estimated that an average of one electric locomotive is necessary for each two or three miles of double-track line. The cost of a 3 000-H.P. locomotive is from £9 000 to £12 000. The cost of electric power measured at the power station varies from 1/4 d. to 1/2 d. per kw.-h., this

TABLE 3

ITEM OF COST.	Steam traction.				Electric traction.			
	Average cost per shunting hour.	Cost per			Average cost per shunting hour.	Cost per		
		Train locomotive-km.	Hauled axle-km.	Actual hauled-ton-km.		Train locomotive-km.	Hauled. axle-km.	Actual hauled ton-km.
	Lire	Lire	Lira	Lira	Lire	Lire	Lira	Lira
Wages	13.816	2.0688	0.06691	0.00831	21.271	2.726	0.06128	0.00839
Fuel	10.221	2.6383	0.08534	0.01060	—	—	—	—
Electric energy	—	—	—	—	15.048	1.770	0.03980	0.00545
Lubrication	0.296	0.0638	0.00206	0.00026	0.255	0.062	0.00140	0.00019
Train heating	—	0.0083	0.00027	0.00003	—	0.124	0.00279	0.00038
Water for locomotives	0.177	0.0456	0 00147	0.00018	—	—	—	—
Locomotive maintenance	8.234	1.9462	0.06295	0.00782	5.454	1.220	0.02743	0.00375
Miscellaneous	4.533	0.7735	0.02503	0.00311	9.548	1.282	0.02884	0.00395
Locomotive renewals	0.104	0.0967	0.00313	0.00039	0.777	0.202	0.00454	0.00062
Line equipment renewals	—	—	—	—	1.287	0.134	0.00301	0 00041
Interest on cost of locomotives	1.200	0.5598	0 01810	0 00225	8.966	1.196	0.02690	0.00268
Interest on cost of line equipment	—	—	—	—	22.662	2.366	0.05319	0.00728
Sinking fund	—	—	—	—	0.433	0.047	0.00107	0.00015
Grand total	38.581	8.2010	0.26526	0.03295	85.701	11.129	0.25025	0.03325

price including interest, sinking fund, and maintenance cost of the high-tension lines which connect the power stations to the railway lines. The maintenance and operating costs of contact lines and substations vary from £180 to £320 per annum per mile, according to the importance of the line. In table 3 are given the operating expenses of the whole Italian railway system for both steam and electric traction. The costs are given in Italian lire and centimes, and refer to a price of 140.13 lire per ton for coal, and of 0.16 lira per kw.-h. for electric power (1).

(1) At the stabilised par rate of 92.46 lire to the pound sterling, one lira = 2.60 d., approximately, and the above prices correspond to : coal, 30 sh. 4 d. per ton, and electricity : 0.415 per kw.-h.

The economic result.

It may be said that the economic result of electrification is easily demonstrated if the coal price is high and the traffic dense, while it is less easily realised if the coal price is low and the traffic small. In addition to these economic reasons which, depending on the market conditions, are sometimes favourable and sometimes the reverse, there are many other considerations which are favourable to a progressive electrification of the railway system in Italy. There is, above all, the fact that with electrification it is possible to utilise the abundant hydro-electric resources of the country, which is thus rendered more and more independent of other countries from which coal is obtained. In Italy, on account of its geographical configuration, railway operation generally presents difficulties

greater than those experienced in other countries. In this connection it may be pointed out that the line now in course of construction between Bologna and Florence which crosses the Apennines on the south of the existing line (the latter, as has been mentioned, has gradients as steep as 1 in 38 and more than 40 tunnels), has a maximum gradient of 1 in 83. To obtain this result, however, it has been necessary to construct a tunnel 11.5 miles long — a length which is exceeded only by the Simplon tunnel.

A wider point of view.

Italians have a lively recollection of the enormous difficulties due to want of coal which they experienced during

Fig. 3. — Aerial frog.

Fig. 4. — Aerial section switch.

Fig. 5. — Longitudinal suspension contact line.

the war. Notwithstanding the considerable diminution of traffic, in many cases freshly-felled timber had to be burnt in the locomotive fireboxes. Electrification has solved the traffic congestion trouble on certain single-track mountain lines which were working at the maximum possible density with steam traction, and has rendered unnecessary projects which were on foot for doubling the existing tracks or for constructing additional lines. For all these reasons the progressive electrification of the Italian railways has to be considered from a wider point of view than the strictly economic one.

Electrical energy.

In the first period of electrification, as already mentioned, the power was produced in generating stations belonging to the railways. In the second period, with greater extension of the electrified lines, power stations were installed equipped partly with 16 2/3-cycle plant for exclusively traction purposes, and partly with 42- or 50-cycle plant for other industrial purposes. Power stations of this type were constructed either by the State Railways or by private undertakings which sold the energy to the railways. With 16-cycle plant in

the power stations it is necessary to employ transformers and transmission lines completely separate from those used for other industrial purposes. Recently, however, it was found convenient to produce and transmit, for traction purposes, energy having the same characteristics as that for industrial purposes. This system facilitates the supply of current to certain lines in cases where it is not possible to construct other generating stations within a reasonably short distance; but, on the other hand, it necessitates the installa-

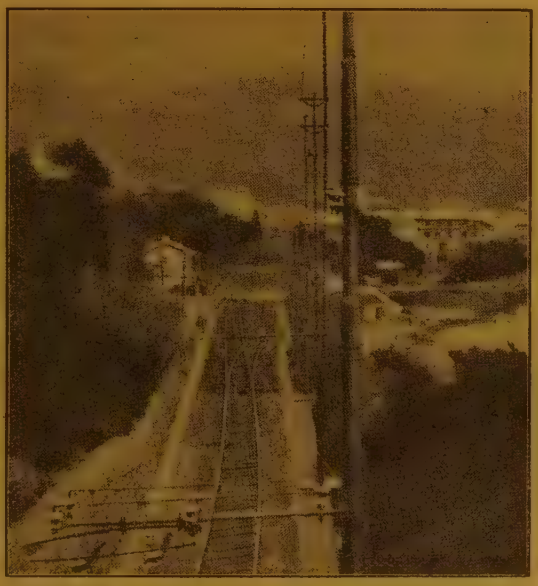


Fig. 6. — Arenzano Station, on the Genoa-Ventimiglia line.

tion of a greater quantity of machinery. Some large substations equipped with rotating machinery for frequency conversion have recently been installed for lines operating on the 16-cycle 3-phase system. Actually, the capacity of the central power stations provided for railway purposes is about 180 000 *kVA*, whilst that of all the Italian power stations is about 2 000 000 *kVA*. It is estimated that the maximum power obtainable from hydraulic resources is about 32 000 million units per annum, when the total generating plant installed will reach 7 000 000 kw.

Electrification a natural course.

If the total electrical energy employed for the electrified lines (347 million kw.-h.) is compared with the total electrical energy produced in Italy (10 000 million kw.-h.) it is seen that barely 3 1/2 % of the total hydraulic power utilised is employed for traction purposes. As the traffic of the lines now electrified represents about 20 % of the total traffic, it is evident that, even if the whole of the railway system were electrified and no more generating stations were constructed, the entire quantity of energy consumed for railway

purposes would represent only a small percentage of the total energy produced. With such an abundance of hydraulic energy and such scarcity of coal as there is in Italy, electrification of the railways is the natural course to adopt. It may generally be said that favourable conditions for electric traction, at least so far as the supply of power is concerned, exist in all those countries in which there is a system of power stations and transmission lines, which assures the economical distribution of electric power throughout the country. In such cases railway electrification represents a transformation which does not differ from that experienced in other industries.

Regenerated power.

It is well known that 3-phase locomotives will restore energy to the line when, on descending gradients, their speed is greater than the synchronous speed of the motors. On lines with heavy gradients the energy given back to the line by the descending trains represents as much as 20 to 25 % of the energy consumed in the ascent. The importance of this regeneration, however, chiefly lies in the greater security of brake operation on heavy gradients. When the energy is regenerated it is possible to run without applying the brakes, and, in the event of an accident, braking may be resorted to with a maximum of efficiency. Another result of the regeneration of energy is the reduced wear of brake shoes, tyres and rails. To regenerate energy with 3-phase locomotives no special operation is necessary. As all goods trains are not, however, provided with continuous automatic brakes, it was necessary to limit the regeneration, as it is not safe to descend with the brakes completely off. In fact, if, during the regeneration of energy, the circuit should anywhere be broken, the train, having every buffer compressed, extends roughly, and the couplings may break. With direct current, energy can also be regenerated; but in this case the process is not automatic as with the 3-phase system. A certain amount of skill and attention is necessary on the part of the driver, as the amount of energy regenerated depends not only on the motor excitation but also on the line voltage, on the train speed, and on the current absorbed by other trains running on the same line. There is still a difference of opinion as to the advantage of regeneration of d.c. systems, especially as either the mercury-arc rectifiers must be abandoned, or, if they are used, the regenerated energy must be dissipated in resistances. From the point of view of economy of energy on Italian mountain lines, regeneration is of primary importance since, as already mentioned, the regenerated energy may amount to as much as 20 % of the total consumption.

Substations and contact lines.

Long experience with the 3-phase system in Italy has led to the establishment of standard types of substations and contact lines. On lines with steep gradients the average distance between two successive 3-phase substations is about nine miles; while it has been recognised that a spacing of 20 miles should not be exceeded even in lines with little traffic, in order to keep the drop of pressure along the contact line as low as possible, since the asynchronous motors of the locomotives are very sensitive to drop of pressure, the drawbar pull diminishing very rapidly (almost as the square of the voltage) as the voltage falls. Four, seven or nine single-phase transformers are installed in every substation, one or two of them serving as reserve to the others. Each set of three single-phase transformers is generally coupled in delta on both the high- and low-tension sides, one phase of the last-named being connected to the running track. The single-phase transformers are of two types, namely, 750 and 2 250 kva.

The switches are of sufficient rupturing capacity to withstand the short-circuits which are more or less frequent on 3-phase contact lines. The substations for industrial frequency installations have nearly the same characteristics as those for 16 cycles. The 3 000-volt d.c. substations, which are installed at a distance of 30 miles apart, transform the high-tension alternating current into 3 000-volt direct current by means of motor-generator sets and mercury-arc rectifiers. Among the many advantages claimed for rectifiers over motor- generators are their insensibility to short circuits, the rapidity with which they can be started up, their smaller operating cost, and their comparatively small size. On the other hand, they induce currents in weak-current circuits, the direct-current wave is a pulsating one, and they are unable to transform direct

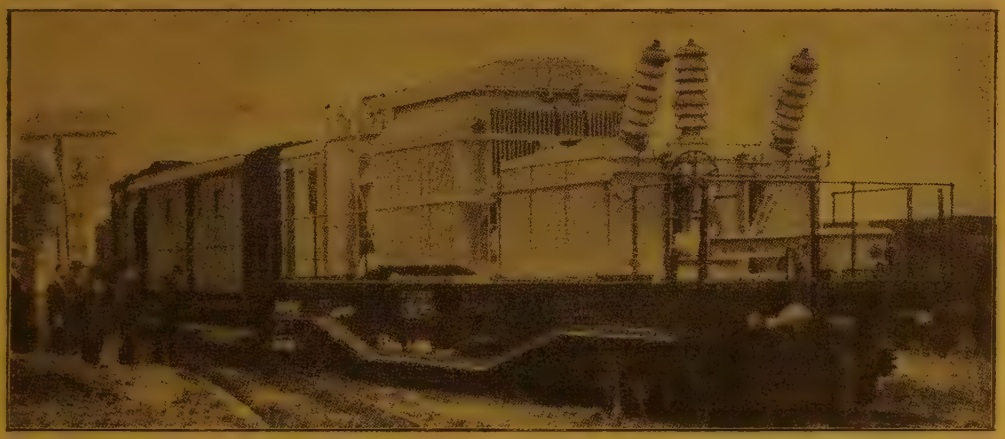


Fig. 7. — One of the travelling transformer substations.

current into alternating current so as to restore to the high-tension line the regenerated energy of the descending trains.

Travelling substations.

In order to meet the eventuality of a substation breakdown which cannot be repaired in a short time, travelling substations have been introduced on the Italian State Railways. These consist of a specially designed railway car on which are installed a 3-phase 2 250-kva. oil-immersed self-cooled transformer and two automatic oil-switches, one for the high-tension side and the other for the low. The total weight of one of these travelling substations is 90 tons. On the 3 000-volt d.c. systems the car is equipped with a 3-phase 2 250-kva. oil-immersed transformer, a 2 000-kw. mercury-arc rectifier, and switches for both the high-tension a. c. and the d.c. sides. These travelling substations, both for 3-phase and d.c. traction systems, have proved so advantageous from both the technical and the economical points of view, not only for emergency service but also for continuous use, that their employment in place of ordinary substations is now considered quite normal. The cost of the travelling substations is only about half that of an ordinary substation housed in a brick and cement building.

Three-phase contact lines.

The 3-phase contact lines present difficulties that are unknown with the single-wire contact line, the greatest difficulty occurring at cross-overs and junctions. Many experiments and tests had, therefore, to be carried out by the Italian State Railways before the present type of switch, giving satisfactory operation even at high train speeds, was evolved. It will be readily understood that in the trolleys of each 3-phase locomotive it is necessary to have a couple of contacts for each phase so as to assure continuity of contact at turn-outs and junctions, these being at a distance apart which must not be less than 26 feet, that being about the distance between the wood insulators on the cross-over contact wires. This is determined by the necessity of there being at least 5 inches between the contact line of one phase and the trolley collector of the other phase. All difficulties presented by 3-phase contact lines in the electrification of single, double and triple pairs of points and in other more complicated cases were, however, successfully overcome.

Nevertheless, the contact system in these cases becomes so complicated, and its installation and maintenance costs so high, that the 3-phase system compares unfavourably with the other systems in this respect.

Industrial-frequency contact line.

The contact line for the 10 000-volt industrial-frequency system presents nearly the same characteristics as the 3 600-volt 16.7-cycle line, but the difficulties are greater at cross-over roads, as in this case it is not possible to have the contact line of one phase and that of the other phase nearer than 10 inches to one another. For this reason it is impossible to extend the contact line over triple pairs of points. It is easy to understand the great difficulties both in installation and operation that the 3-phase industrial-frequency system presents in the electrification of large stations with many tracks and turn-outs. The contact line for the 3 000-volt d.c. system is, on the other hand, very simple to install. Generally, a catenary suspension is used which does not differ very greatly from those of other similar installations.

Electric locomotives.

On the 1 013 miles of the Italian State Railways now electrically operated, 791 electric locomotives are working. It may be pointed out that these 791 electric locomotives are doing the same service as 1 200 steam locomotives with five, four or three coupled axles, of the most recent types. At the end of the present year the total number of electric locomotives in operation will reach 888, and may be classified as shown in table 4. The total distance run every year varies according to the lines and type of locomotive. The locomotive for mountain lines, where the highest speed is only 32 m.p.h., covers a distance varying from 30 000 to 50 000 miles a year, while passenger locomotives may run as many as 70 000 miles each year. The periodical examinations and the locomotive repairs are generally carried out in the shops adjacent to the engine sheds. There are fifteen such shops, in five of which motor repairs are also carried out. According to the type of locomotive, a thorough overhaul is carried out every eighteen months or two years of uninterrupted service, during which the locomotive is inspected every 7, 10 or 15 days. For these examinations the locomotive is not kept in the shed for longer than a day. As regards heavy repairs, it has been recognised that these can best be done in central depots, which are more completely equipped than the shops attached to the engine sheds. With electric locomotives it is essential that repairs should be car-

Fig. 8. — Electric locomotive E. 551, built by the Ansaldo Soc. Anon., of Genoa, for the Italian State Railways.

ried out as quickly as possible in order to reduce to the minimum the period during which the locomotive is laid up. This becomes a simple matter when the locomotives are only of a few standard types, and all the most recent locomotives are now so standardised. Actually the number of locomotives under or awaiting repair is about 20 % of the total. On some lines it is as small as 10 to 12 %. From the data given in table 3 it will be seen that the maintenance cost for an electric locomotive is low compared with the corresponding cost for a steam locomotive.

Three-phase locomotives.

The principal reason for the adoption of the 3-phase system on the Italian State Railways was the simplicity of the electric locomotive employed; for, since 1920, the 2 400-H. P. 5-coupled E. 550 type locomotives, weighing only 60 tons and with two speeds of 16 and 32 m.p.h., have not been excelled either for simplicity or lightness. Various types of electric locomotive have been constructed in Italy from 1902 onwards, but, of recent models, the E. 554 type for goods and passenger service on mountain lines and the E. 432 type for passenger service at speeds of 62 miles an hour are, perhaps, of outstanding interest. The E. 554 type locomotive, which has a 0-10-0 wheel arrangement, has a length over buffers and a wheelbase of 12.1 feet, the distance between extreme axles being 21.65 feet and the diameter of the driving wheels 3 ft. 5.9 in. Its continuous tractive effort at 15 m. p. h. is 26 400 lb. and at 31 m. p. h., 28 660 lb., while the continuous power of the motors is 2 000 kw. Current is collected by means of the usual 3-phase trolley, or bow. Like other locomotives having only two speeds, it is simple both mechanically and electrically. Locomo-

tives having more than two speeds, for instance, four, are more complicated. Generally, the four speeds are obtained by changing the number of the poles and connecting the motors in cascade and parallel. At the two first speeds, obtained by connecting the motors in cascade, the power factor is somewhat low (about 0.7) and the maximum tractive effort is considerably less than in

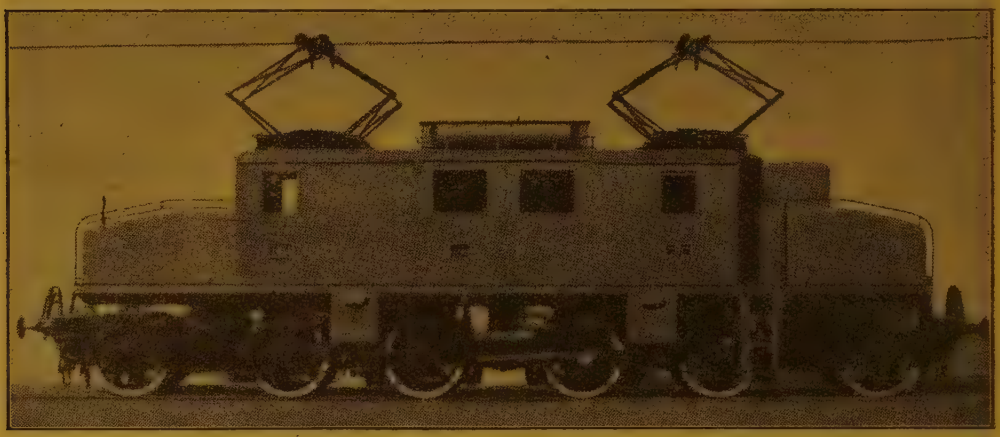


Fig. 9. — Electric locomotive E. 625, built by the Societa « C.E.M.S.A. » of Saronno, for service on the Italian State Railways.

the case of parallel coupling. Recently, however, types of winding have been designed which allow three different numbers of poles to be obtained, while always employing every conductor of the winding and without recurring to phase transformers. By this means three speeds out of four are obtained with the motors connected in parallel.

Passenger locomotives.

The E. 432 locomotives for passenger services run at from 23 to 64 m.p.h. and have a length over buffers of 45.93 feet, a rigid wheelbase of 6.88 feet, and a distance between extreme axles of 49.9 feet. The 2-8-2 wheel arrangement has been adopted on this locomotive, the diameter of the driving wheels being 5 ft. 3 in., while the continuous tractive effort at 23 m. p. h. is 18 739 lb., at 32 m.p.h. 26 455 lb., at 46 m.p.h. 26 455 lb., and at 64 m.p.h. 15 432 lb. The leading truck of these locomotives is of the so-called « Italian » type, while the transmission system from the motors to the axles is arranged by means of Bianchi articulated connecting rods. The first of the four operating speeds (23 m.p.h.) is obtained by connecting in cascade the motors with 8 poles. For the other speeds the motors are coupled in parallel with 12 poles for 32 m.p.h., 8 poles for 46 m.p.h., and 6 poles for 64 m.p.h. This is effected by means of the special winding of these motors. According to the way in which the terminals of these windigs are connected, the three requisite numbers of pole may be obtained. In the connections of the sections of the winding in order to obtain 12 poles, the motor has the three phases connected in star. In the connections of the sections of the winding to obtain 8 poles, the motor is still 3-phase. To obtain 6 poles the winding terminals must be so connected as to

TABLE 4. — **Details of locomotives.**

Denomination.	Number of coupled axles.	Power.	Speed.	Total weight.	Number of locomotives.
		16-cycle 3-phase locomotives.			
		Kw.	M.p.h	Tons.	
E 550.	5	1.500	16-32	64	186
E 551.	5	2.000	16-32	75	183
E 552.	5	1.800	10-20-32	73	15
E 554	5	2.000	16-32	76	183
E 431.	4	2.000	23-32-46-64	92	37
E 432.	4	2.200	23-32-46-64	93	40
E 330.	3	2.000	23-32-46-64	72	16
E 331.	3	2.000	23-32-46-64	90	18
E 332.	3	1.800	23-32-46-64	90	6
E 333.	3	1.800	16-32-46	73	40
E 360.	3	1 000	22-44	70	3
E 380.	3	1.000	22-44	70	2
E 390.	3	1.000	14-28	70	2
				Total. . .	731
		Industrial-frequency 3-phase locomotives.			
E 570.	5	1.800	16-32	70	4
E 470.	4	1.800	23-32-46-64	92	4
E 472.	4	2.000	23-32-46-64	93	10
				Total. . .	18
		3 000-volt d.c. locomotives.			
E 625.	6	1.800	Up to 32	90	8
E 626.	6	1.800	Up to 50	90	6
E 626.	6	2.000	Up to 50	90	85
E 326.	3	2.000	Up to 75	107	12
				Total. . .	111
		650-volt d.c. locomotives.			
E 320.	3	1.200	55	68	5
E 321.	3	1.200	55	68	17
E 420.	4	350	40	60	1
E 620.	6	600	46	60	5
				Total. . .	28

constitute a 2-phase system. To enable the motors to be fed direct from the contact line, without having recourse to a Scott transformer, the windings of the two motors are connected in series. The voltage of one phase is greater than that of the other, but, practically, the characteristics of the motor are still good. The winding of the rotor is of the direct-current type, with 48 tappings connected to 13 collector ring. The improvements and simplifications introduced in the most recent types of the 16.7-cycle 3-phase locomotives have, in fact, made these locomotives the equal of any other.

Industrial-frequency locomotives.

The industrial-frequency 3-phase locomotives built by the Italian State Railways up to this date are of the three types mentioned in table 4, and it may be said that, generally speaking, they present similar features to the 16-cycle locomotives. In addition, on these locomotives a transformer is installed which reduces the contact line voltage from 10 000 volts to the motor voltage, which is about 900 volts in each of the three types. The motors have 6, 8 or 12 poles, and gears are employed to obtain the speeds of 23, 32, 46, and 64 m.p.h. As two motors are installed in every locomotive, and the driving wheels are four or five in number, connecting rods, in addition to the gears, are used to transmit the torque. These locomotives are, therefore, more complicated than those for 16 cycle. Moreover, the trolleys do not work so well on the 10 000-volt contact line, especially at turn-outs and section gaps and at the highest speeds, as in the case of 3 700 volts and 16 cycles. The superiority of the industrial-frequency system over the 16-cycle system lies in the fact that the substations may be as much as 30 miles apart. The transformers for 45 cycles are smaller, lighter and cheaper than those for 16 cycles for equal output.

Direct-current locomotives.

The only section of the Italian State Railways actually in operation at 3 000 volts direct current is the Foggia-Benevento line, although the Benevento-Naples trunk line is now being electrified. As has previously been mentioned, it has been decided to extend the direct-current system to other lines in Southern Italy and to the new line between Bologna and Florence and most probably in the future to lines in Northern Italy also. The d. c. locomotive has been designed with a view to standardising both the mechanical and the electrical parts of the various types of locomotive, bearing in mind future requirements. To attain this object, types of locomotive which are the most suitable for satisfying the various operating requirements have been designed. It has been found that these types can be reduced to three only. All three types of locomotive have been designed with a view to standardising the various parts, both mechanical and electrical. The result has been that for the three types there are only two types of axles and gears, one type of gearbox, one type of axle bearing, and brakes with interchangeable parts, so that all the mechanical parts liable to deterioration are reduced to one or two standard types. As regards the electrical arrangements, standardisation has been obtained in the most complete way; for example, the same type of motors, contactors, controllers, resistances, starting compressors, fans, etc., have been adopted for each type. The design both of the d.c. locomotives and of the 3-phase locomotives has, indeed, been studied in every particular, both mechanical and electrical, by a special department of the Italian State Railways. This has rendered available the valuable experience directly obtained on operating locomotives in order to avoid or correct, in future designs, any faults which may have been found. The specifications thus obtained are submitted to the manufacturing firms.

[669 (.43)]

A new process for cleaning metal parts in railway workshops,

by Mr. BÜRKLEN, Reichsbahnbaumeister, Paderborn.

Figs. 1 and 2, p. 786.

(From *Glasers Annalen*, 1930, No. 1269, p. 107.)

A brief survey is first given of the usual methods hitherto employed. The major part of the article is devoted to describing the operation of a new metal-washing machine, the « Hydromatikus », in cleaning and removing grease from metal parts. The method of using the machine in the repair shops at Paderborn (Central) is described, and particularly its employment as the cleaning part of the work in a continuous-flow system of shop operation.

There is good reason for the growing attention that is given to the treatment of metallic and non-metallic surfaces. An important field for such treatment is the preliminary cleaning necessary prior to lacquering, painting, galvanising, assembling, and reconstruction of parts of engines and rolling stock.

The mechanical parts of the rolling stock on the German State Railways become fouled to an extraordinary extent in service by dirt and oil, and thorough cleansing is a necessary preliminary to any inspection or work. The oil must be dissolved, the dirt softened and both removed from the various parts.

The processes usually employed up to the present time will first be outlined. the oldest and the most generally used, even today, is : *boiling the parts.*

The parts are boiled in a vessel containing a caustic soda solution or other grease remover. The bath is heated either by injecting steam into it, or by steam-heated coils. The dirt is loosened by agitating the lye either by blowing in steam, or by circulating the liquid by a pump; if desired, the parts may also be moved about or dipped in and out. When boiling has gone on long enough, any dirt that still adheres is removed by jets of hot water applied in another tank.

Owing to the mess associated with the process, the fumes and the space required, boiling plants are usually installed away from the workshops and this occasions costly transport.

The trichlorethylene (systems of Max Heller-Christ patended, Wacker, etc.) is of a purely chemical nature.

The oil is dissolved from the parts to be cleaned by means of trichlorethylene ($C_2H\ C\ 1_3$) contained in a closed vessel. The washing drum is heated by a jacket and is revolved by suitable mechanism. This type of plant is used for dealing with cleaning cloths, lubricating pads, fittings and other material.

The trichlorethylene and the oil are recovered.

The spraying system.

This is included for the sake of completeness. The frames, bogies and wheels of the locomotives that are being repaired are sprayed with hot water under a pressure of 5 to 18 at. (71 to 256 lb. per sq. inch). This obviates the necessity of having to make the cleaning plant which deals with the other parts, of the large size necessary for the big pieces.

A novel method is embodied in the « Hydromatikus » metal washing machine for cleaning and removing grease from metal parts.

So far as the writer is aware, this system was used for the first time, on the same scale as boiling plants, in the State Railway repair shops at Durlach.

The other plants of the same kind installed at the Berlin-Schöneweide, Munich, Schwetzingen, Stuttgart (North) and Cannstatt workshops, are of smaller size and are used only for cleaning small parts.

When the large installation was put down at Paderborn (Central) successful attempts were made to utilise all the earlier experience with Hydromatikus plants, and to ascertain how the cleaning of locomotive parts could be carried out most economically.

The principle of the Hydromatikus may be described briefly as follows :

The parts to be cleaned pass through the machine on a conveyor which can be run at three different speeds. The machine has two separate chambers; in the first, the washing chamber, powerful jets are directed from all sides of cleaning liquid at 85° C. (185° F.). In the second chamber, the rinsing compartment, water at 75° (167° F.) is similarly sprayed on to the parts to remove completely any dirt that may still be adhering.

The supply of scouring and spraying liquid at the base of the machine is heated by coils through which live of exhaust steam is circulated.

From thence the warm liquid passes into a vessel, at the side, from which it is drawn by pumps through automatic sludge separators and sprayed into the chamber. The cleaning liquids are not wasted when they have been used but work in a complete cycle, and need only be renewed at definite intervals.

The oil and dirt are loosened by hot solvent (caustic soda or similar chemical) and the dirt is removed from the metal parts by the force of the streams of liquid in both the compartments.

The Paderborn machine is of the two-compartment design and has the following dimensions :

Overall length 18.8 m. (61 ft. 8 in.); length of washing compartment 8 m. (26 ft. 3 in.); length of rinsing compartment 5 m. (16 ft. 5 in.); receiving table 2 m. (6 ft. 6 3/4 in.); delivery table 3 m. (9 ft. 10 1/8 in.); width of conveyor 2 m. (6 ft. 6 3/4 in.); pump for washing compartment 15 kw., 2 300 litres (81.2 cubic feet) per minute; pump for rinsing compartment, 7.5 kw., 1 200 litres (42.3 cubic feet) per minute; motor for conveyor, 3 kw.; speeds of conveyor 0.25 m., 0.50 m. and 0.75 m. (0.82, 1.64, 2.46 feet) per minute.

Compared with previous machines, the following improvements have been made in the construction : the fumes from the two compartments are drawn off by means of an exhaust duct in the roof of the machine. The exhaust duct is carried down the side to the floor and enters a pipe which communicates with the smithy chimney. (The draught should be only sufficient to ensure that the fumes are drawn away from both ends of the machine.) Two throttle valves in the exhaust duct enable the chimney

draught to be regulated and loss of heat to be avoided, and these are adjusted to suit the chimney draught, the volume of fumes, the outside temperature and the strength of the wind.

Sludge separators of special design with a number of overflows and filtering grids hold back the dirt that is washed off the parts being treated.

A point of some importance is that no foundations are required as the machine is supported on its own framework. It is advisable to mount it over a pit for the purpose of inspection from below.

The conveyor is carried 3 m. (9 ft. 18 1/8 in.) beyond the exit from the rinsing compartment and this portion is slightly inclined downwards. At the end of the extension the cleaned material is deposited on a fixed table of flat plate. From here the parts are distributed to the various shops by electric trucks and trailers.

The stopping and starting of the conveyor is effected by two push buttons placed handily for the attendants at the entrance to and outlet from the machine, and this arrangement gives a large measure of safety and convenience.

The washing liquid is heated to about 90° C. (194° F.), and the rinsing liquid to about 70° (158° F.), by steam-heated coils. When the whole of the liquid has reached the required temperature the quantity of steam used is only that necessary to make up for the heat losses. The latter are made up chiefly of the heat carried away by the parts that are cleaned, the heat in the fumes drawn off, and in the liquid that adheres to the cleaned pieces, and also the convection and radiation losses from the casing. The heating up of the material cleaned has the advantage that it dries immediately it leaves the machine. The convection and radiation of heat from the casing has been reduced to a minimum by the use of heat insulation.

The latter consists of slabs of insulating brick 50 mm. (2 inches) thick held in place by strong zinc-wire netting; the surface is smoothed and lined with canvas and finally varnished. The economy in heat consumption paid for the insulation in 15 months.

As the total heat consumption of the machine is approximately 650 kgr. (1 430 lb.) of steam per hour, the question of the economical working of this side of the plant cannot be neglected. For this reason the steam-heating coils have been made large enough to permit of the use of exhaust steam from the smithy hammer. The steam supply, condensate and water pipes and the electric cables are laid in a special trench which contains also the fume exhaust duct; the condensed water is taken back to the pure water tank in the boiler house.

The operating costs are carefully controlled by steam meter, water meter, electricity meter and records of the quatity of soda used. The motor control and starting gear is arranged on a switchboard fixed on one side.

The hot caustic soda solution used retains its power of removing grease for more than one day, and therefore the front portion of the pit under the Hydromatikus is constructed as a settling tank. Next morning the clear liquid is returned to the machine by a special pump, the sludge remaining until a favourable opportunity occurs for washing it out.

Operation and economy of the Hydromatikus.

After careful consideration, the machine was installed in the erecting shop

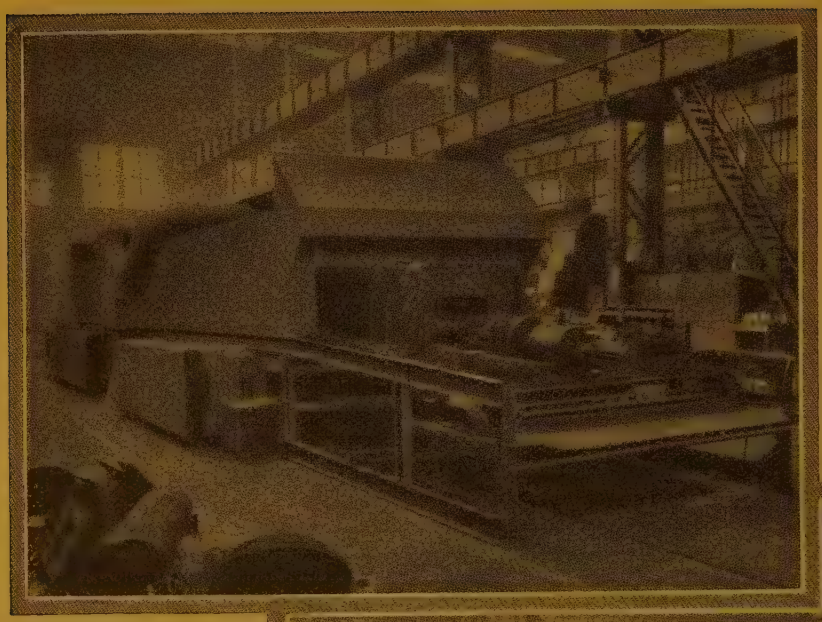


Fig. 1.

Delivery end of machine showing inclined extension of conveyor. The fumes are drawn off from the top of the machine into a pipe underneath the floor and discharge into a chimney. On the left-hand side are two sludge separators for the washing and rinsing machines respectively.

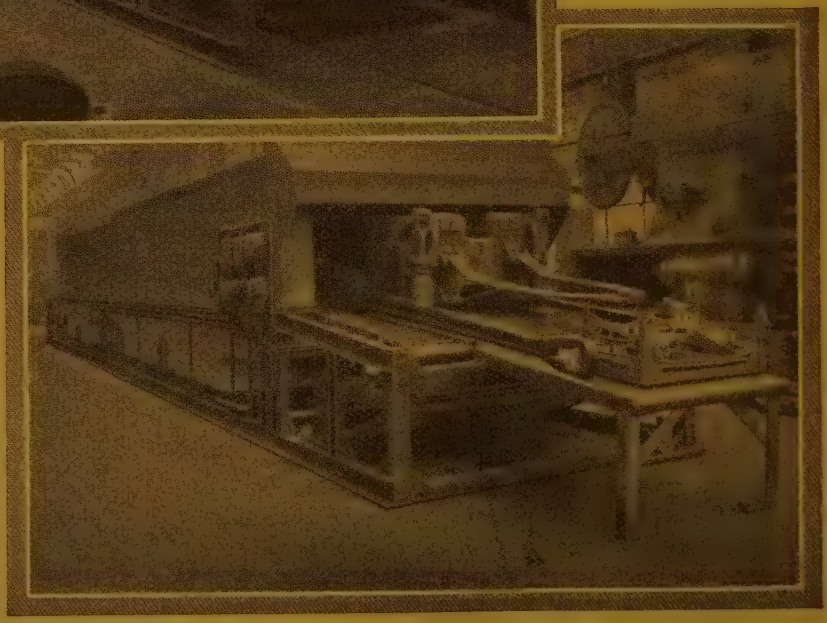


Fig. 2.

Entrance end of machine. There is a special loading table in front of the conveyor extension. Switchboard on the left-hand side controls the whole of the motors. Push buttons at both ends of the machine enable it to be stopped quickly and safely.

Hydromatikus metal-washing machine in a repair shop of the German State Railways. Two-compartment type with washing und rinsing chambers.

Width of tunnel : 2.00 m. (6 ft. 6 3/4 in.).
Height of tunnel : 0.85 m. (2 ft. 9 1|2 in.).
Length of washing compartment : 7 m. (22 ft. 11 1/2 in.).
Length of rinsing compartment : 5.70 m. (18 ft. 8 in.).
Overall length including conveyor extensions : 17.00 m. (55 ft. 9 in.).

Capacity : 1 G 12 locomotive in about 5 hours, exclusive of wheels, frame, cab and boiler.

adjacent to both the stripping pits, that is to say, at the spot where the work commences. This point appeared to be the most suitable as the machine then fits into the flow of operations. The lighter parts to be dismantled are immediately put on to the conveyor, whilst the heavy pieces are transferred by a crane. In this way the former transport to the boiling plant is eliminated and the stripping pits are no longer occupied with a collection of parts which hampers progress. The conveyor takes the dismantled parts in a continuous stream and moves them towards the points where they are to be repaired.

All parts of locomotives are cleaned except the frames, boilers, wheels and cabs; the cleaning machine deals with rods, pipes, plates, steps, pumps, axle boxes, screws, fittings, etc...

Small parts are collected in wire trays before placing in the machine. The provision of three speeds on the conveyor affords a good means of adjusting the progress to the volume of work and to the amount of dirt on the parts. Excellent cleaning is effected. Even encrusted dirt and caked oil, soot and other substances are entirely removed.

The operation of the machine is as simple as can be imagined and no preliminary cleaning even of the dirtiest piece is found to be necessary. No disturbance to the work of the shop is occasioned by the washing machine and it operates without smell or noise, and is clean, safe and automatic.

From the point of view of economy, the advantages of the new machine over previous systems depend upon its erection at the point of dismantling, the saving of steam and the reduction of hand cleaning, handling and working expenses. The whole process of cleaning is carried out more quickly and with greater efficiency.

The costing system which gives the cost for the whole of the parts of a locomotive showed that the economy, compared with a boiling plant, is such that the outlay on the new plant can soon be written off.

The Hydromatikus cleaning machine has therefore proved itself to be a valuable, economical and speedy method for mechanical cleaning of dirty parts.

[656. 281 (.42)]

Railway accident reports.

Figs. 1 to 8, pp. 789 to 796.

(*The Railway Gazette.*)

I — Derailment at Weaver Junction, London Midland and Scottisch Railway, 14 January 1931.

The leading coupled wheels of the engine — No. 6131, *Planet*, 4-6-0 type, three cylinders, simple, Royal Scot class — of the 1.30 p. m. Euston to Glasgow left the rails 53 yards in advance of the Liverpool line facing points. No other wheels of the engine or train appear to have been derailed, and the train was brought to a stand by the driver in 1 091 yards from the point of derailment. There were no personal injuries, and the damage done to the engine and permanent way was unimportant; there was no damage to rolling-stock.

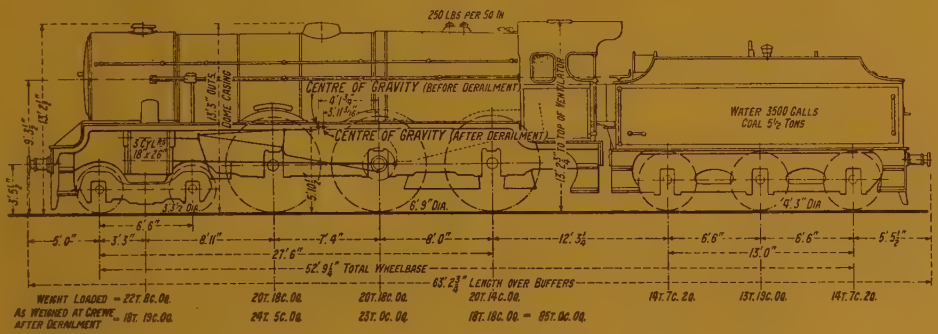
Weaver Junction is 174 1/8 miles from Euston, and 16 1/8 miles north of Crewe. The station immediately to the south is Acton Bridge, 172 1/4 miles, whence the line falls 1 in 330 to mile 174 and afterwards passes over Dutton Viaduct, 492 yards long, on a rising gradient of 1 in 1 096, to Weaver Junction, where the gradient becomes again 1 in 330, falling. The line is straight across the viaduct, and for the 40 or so yards beyond that to the facing points mentioned above. There a curve commences, which is right-handed in the direction of travel and, as we read the report, of 30 chains radius at the crossing of the Liverpool line junction. The angle of the crossing is 1 in 20. The layout of the junction makes it possible to give super-elevation for high speed for both the North and Liverpool directions, and the regulations lay down a maximum speed of 55 m.p.h. through the junction for trains going north.

Colonel Anderson inquired into the accident, and reports that driver J. Kay stated that he was aware of the restriction of speed, and that he estimated that he was travelling at 56 m.p.h. over the viaduct, and between 50 and 55 m.p.h. through the junction. He left Crewe two minutes late, and was three minutes late at Weaver Junction. The guard did not think the train was travelling faster than usual, or at the 70 m.p.h. suggested by later witnesses. The signalman at Acton Bridge did not notice that the speed was higher than usual, but the man at Weaver Junction thought that it was faster.

The permanent-way inspector said that, as part of his duty, he timed a certain number of trains through the junction once a month. The timing was done over a length of 220 yards with a stop watch and a piece of string, which the engine broke on passing the point where it was tied to the rail. Judged by his timings, he thought about 50 p. c. of the trains checked by him exceeded the maximum speed permitted. Two men who were at the plate-layers' cabin opposite Weaver Junction signal-box when the train passed both estimated the speed of the train as nearer 70 than 55 m.p.h. when it passed them..

The records of the Operating Department show that, during the last six months, the above-mentioned complaints

as to excessive speed at this point have been substantiated in very few cases indeed. Tests with a dynamometer car also showed that a maximum speed of over 70 m.p.h. between Acton Bridge and Weaver Junction signal-boxes is not inconsistent with the observance of the speed restriction of 55 m.p.h. through the junction. The permanent way at the site of the derailment, and for upwards of a mile south of it, consists of 95-lb. O.B.S. rails, 60 feet long, carried in 4.5-lb. chairs on wooden sleepers — 24 chairs to the 60-foot rail. Each chair has three coach screws, except on the viaduct, where two screws and two round spikes are used. The ballast is granite, of good quality and ample quantity. The standard of maintenance of this main line, which carries high-speed traffic, is of the best, and a careful examination revealed no large variations in either gauge or super-elevation. On the viaduct there were several places where, owing apparently to difficulty in drainage, maintenance is, perhaps, rather more difficult



		Loaded.	*Light.*
Total weight	Engine	= 84 t. 18 c. 0 q.	77 t. 18 c. 2 q.
	Tender	= 42 t. 14 c. 0 q.	21 t. 11 c. 2 q.
	Engine and tender	= 127 t. 12 c. 0 q.	99 t. 11 c. 2 q.

Fig. 1. — Diagram of London Midland of Scottish Railway « Royal Scot » locomotive, with essential particulars.

than elsewhere; but these were in good order when inspected, and the company's officers informed Colonel Anderson that no special work beyond ordinary maintenance had been done anywhere since the accident.

The company's Chief Engineer said that the crossing had been changed, on 2 January, in the ordinary course of maintenance. Its life is normally about two years, at the end of which time it has to be changed because the nose is « crushed over » to the left by the blows from the wheels of passing trains to such an extent as to cause tightening of the gauge on the adjoining Liverpool road.

The first mark of derailment was apparently that of a flange climbing on the outside edge of the head of the check rail. This check rail is on the inside of the curve, opposite the « V » crossing, and the mark referred to was at a point about 7 feet before reaching the nose of the crossing. It was thus made before the left-hand wheel of the same axle had reached the throat of the crossing.

After the derailment, the left-hand leading coupled wheel appears, from the

marks, to have run along the top of the crossing and outside the left-hand rail, breaking fish-bolts, chairs and keys. Similar damage was done to those on the right-hand side. The axle appears to have remained suspended at a level high enough to do no damage other than that indicated, *i.e.*, it only dropped about 3/4 inch to 1 inch below its normal running position.

The gauge of the track between the end of the viaduct and the facing points was exact when inspected by Colonel Anderson. The variations on the curve approaching the viaduct were very small, usually 1/16 inch slack, but in two places it was as much as 3/16 inch slack. On the lead, the gauge varied between about 1/16 inch and 1/8 inch slack, the latter at the first mark of derailment. At the nose of the crossing it was exact. The super-elevation increased regularly at the rate of about 1 inch in 60 feet from about two rail lengths south of the north end of the viaduct. At the toe of the switch it was 2 1/8 inches, at the point of derailment 3 1/8 inches, and at the nose of the crossing 3 1/4 inches. For a speed of 55 m. p. h. this super-elevation of 3 1/8 inches by calculation, was correct for a radius of about 56 chains, whereas the radius of the lead, as measured after the derailment, varied from 66 chains to 30.5 chains.

The engine had run about 124 162 miles since it was built. The wheels had been turned, and axleboxes, etc., refitted in May, 1929; since then it had run about 31 285 miles. After the derailment, it was taken to Crewe for examination, and before stripping, was weighed, with the results shown on the diagram. The company's Chief Mechanical Engineer considered that the derailment would account for the discrepancy between the designed weights and those then found. The excessive weight on the derailed axle is, however, noticeable. With the weights as shown after derailment, the centre of gravity is shifted about 2 inches in rear of its designed position.

Owing to wear of axleboxes and horn guides, the actual total side play, extreme right to extreme left, of the wheels, with reference to the main frames was : Leading coupled, 3/32 inch; intermediate coupled, 5/16 inch; trailing coupled, 13/32 inch, as compared with a normal total of 1/4 inch in each case. It would thus appear that the flange of the intermediate coupled wheels could hardly be in close contact with the outer rail on this curve at the point of derailment.

The flange profiles adopted on the tyres of this engine were those of the B. E. S. A. Specification No. 276 — 1927. Those of the bogie, leading coupled, and trailing coupled wheels were contour « A » thick, and those of the intermediate coupled wheels contour « G », intermediate.

Both the leading coupled wheels bore a number of small marks on the flanges, probably the result of the derailment, and it is difficult to settle which occurred first. But there was a very definite mark on the flange of the left-hand wheel, which was consistent with the striking of the crossing, and another slight one about 6 ft. 6 inches, measured circumferentially, further back on the inside of the right-hand flange. The latter mark on the flange was very small, perhaps 1/2 inch long, and looked like an abrasion. The closeness of the correspondence of the distance between these marks with that between the nose of the crossing and some of the more or less vertical marks on the outside vertical face of the check rail makes it possible that the latter mark was at the point where the right-hand wheel first climbed the check rail. There were no marks which would suggest that any other wheels had been derailed on this occasion.

The conclusions of Colonel Anderson

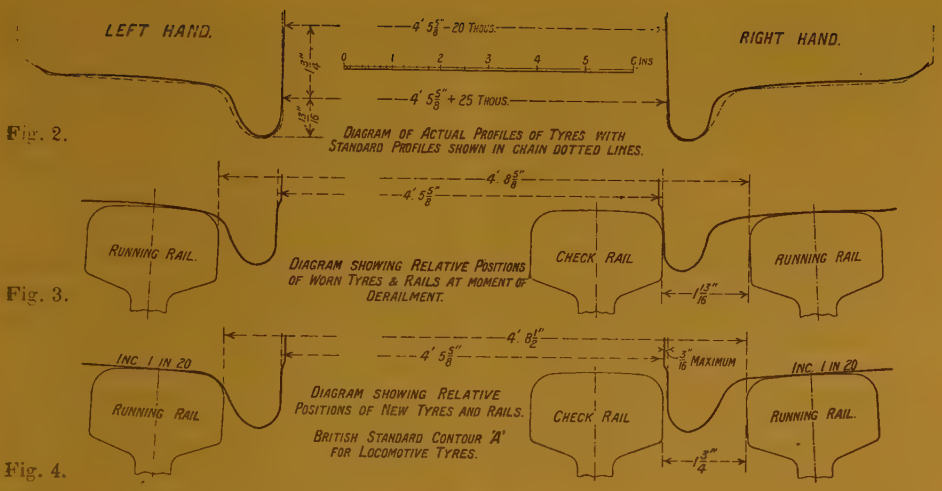

LEFT HAND.
4' 5⅝"–20 THOUS.
RIGHT HAND.
0 1 2 3 4 5 6 INS
4' 5⅝" + 25 THOUS.
DIAGRAM OF ACTUAL PROFILES OF TYRES WITH STANDARD PROFILES SHOWN IN CHAIN DOTTED LINES.
4' 8⅝"
4' 5⅝"
RUNNING RAIL.
DIAGRAM SHOWING RELATIVE POSITIONS OF WORN TYRES & RAILS AT MOMENT OF DERAILMENT.
CHECK RAIL
RUNNING RAIL
1 13/16"
4' 8½"
4' 5⅝"
INC. 1 IN 20
3/16" MAXIMUM
INC. 1 IN 20
RUNNING RAIL
DIAGRAM SHOWING RELATIVE POSITIONS OF NEW TYRES AND RAILS.
BRITISH STANDARD CONTOUR 'A' FOR LOCOMOTIVE TYRES.
CHECK RAIL
RUNNING RAIL.
1 3/4"

Fig. 2.

Fig. 3.

Fig. 4.

Figs. 2 to 4.

are that the marks on the check rail and wheel leave little doubt that the right leading coupled wheel of the engine, when travelling at high speed round this right-handed curve, climbed the check rail at a point about 7 feet before reaching the nose of the crossing, and therefore, before the left-hand wheel on the same axle had reached the throat of the crossing. There is no evidence to show that there was any one defect in engine or track which would account for this, and after prolonged investigation, he can only conclude that the climbing was due to a combination of several causes, the first of which was high speed.

The driver's and guard's evidence shows that a full brake application, made on an ascending gradient of 1 in 330 and probably not more than a train length beyond the point of derailment, only brought the train to a stand in 1 091 yards from that point. Allowing for the distance travelled before the driver's action took effect, the train, therefore, was only stopped about 850 yards after the brake was fully applied; and Colonel Anderson concludes that driver Kay, influenced perhaps by the fact that he was running late, seriously underestimated his speed through the junction. In his opinion, the derailment probably occurred at about 70 m.p.h. Having regard to the curvature and super-elevation at this junction the regulation speed of 55 m.p.h. appears to be certainly the maximum permissible at this point, and driver Kay must therefore accept some measure of responsibility for the accident.

To understand the other contributory causes it is necessary to consider the forces set up by the passage of the engine round the curve at high speed. By calculation the centrifugal force set up under these conditions by this engine with a designed weight of 84.9 tons (without tender) on a 30 1/2-chain curve amounts to 13.9 tons at 70 m. p. h., or 8.6 tons at 55 m. p. h. Allowing for the super-elevation, calculation further shows that the total weight on the inner wheels of the engine is reduced on this curve, at 70 m.p.h., to about 74 %, and at 55 m.p.h. to about 89 %, of its designed amount. On this basis, at the speed of

70 m. p. h., the designed weight of 10.4 tons on the right leading coupled wheel would thus be reduced to about 7.7 tons. If, however, derailment took place, as is possible, at the moment when the hammer blow of this wheel was at its maximum and negative, *i.e.*, upward, value, a further reduction of about 2.7 tons is possible, so that the pressure of this wheel on the rail might then have been only about 5 tons, *i.e.*, less than half the designed amount, and the possibility of lifting correspondingly increased. At 55 m. p. h. the pressure would be about 7.6 tons. There might also be a further small reduction of weight due to the gyroscopic effect of the rotating wheels, but a rough calculation indicates that its value is negligible compared with the above figures.

In addition to this effect of lightening the load on the inside wheels, motion round a curve sets up lateral forces between the flanges of certain wheels and the rails, which in effect guide the engine round the curve. The amount and distribution of these forces cannot be exactly determined, and tests on this point were made by request at the site of the accident on 30 March. At 54 m.p.h. a similar engine and train ran smoothly round the curve. Paint of different colours, applied to the flanges, showed that these lateral forces on the engine were taken up almost entirely by the leading bogie and leading coupled wheels, and the measurements of the displacement of the bogie centre, referred to below, were made at the same time.

Figure 3 reproduced shows the position, with reference to the running rails and check rails, which the tyres of the leading coupled wheels must have taken up under the conditions which existed at the moment when the right leading coupled wheel climbed the check rail. It will be seen that owing to the combined effect of the flange wear, the slack gauge of the track, and the wear of the side of the check rail resulting in increased check rail clearance, the whole of the lateral forces on this axle must have been concentrated at the point of contact of the inside face of the right leading coupled tyre and the outside face of the head of the check rail. These faces make a slight angle with one another, measured in a horizontal plane, owing to the curvature of the track, and, under the pressure resulting from the high speed, in this case cutting and climbing of the flange on the check rail must have occurred, as is shown by the marks on the contact edge of the head of the check rail.

Figure 4 on the diagram, which should be compared with figure 3, shows the relative positions of tyres and rails when flanges are new and the track gauge and check rail clearance correct. It will be noticed that in the latter case the risk of climbing is reduced because all, or nearly all, the side pressure is taken between the curved working surface of the outside of the left-hand flange and the head of the running rail.

The other contributory causes of this derailment appear, therefore, to be the unfortunate combination of worn flanges, slightly slack track gauge, and increased check rail clearance, as actually existing at the time.

The other marks on the head of the check rail, apparently older than, but not altogether dissimilar from, that made by the derailed flange, might, at first sight, be taken as indicating that this is not the first occasion on which a flange has mounted this check rail. If this is their real cause, they indicate previous breach of the speed regulations, to which the short life of the nose of the « V » crossing also lends confirmation. But in the course of the inquiry it was found that there may be in existence some goods wagons with an inside shoulder on their tyres, somewhat similar to that allowed in the standard locomotive tyre contours. There is a possibility that, owing to such wagons not having been stopped soon

enough for turning up of worn tyres, these shoulders might come in contact with the check rail and make similar marks. Whichever, therefore, of these causes is the correct one, the existence of these marks on the check rail referred to is a matter to which the company's attention should be directed.

At the trial already referred to a device was fitted on the engine which recorded the lateral movement of the bogie centre with reference to the main frames of the engine, against the side control springs. This movement amounted to 3/4 inch at the points of this junction, and to between 3/8 inch and 1/2 inch on the rest of the lead. The latter was equivalent to a lateral pressure exercised by the side control springs of about 0.9 to 1.0 ton. This is, therefore, roughly the amount of the total lateral guiding force at 54 m.p.h. exercised by the bogie on the engine running round this curve, which had been improved subsequent to the derailment, and on this occasion was found to be of about 48 chains radius at the crossing. It thus seems that the remainder of the greater lateral forces, due to traversing the curve at still higher speed, must have been taken up almost entirely by the leading coupled wheels, and that, therefore, at the time of derailment these forces were, for the reason already indicated, applied at the point of contact between the inside face of the right-hand tyre and the check rail.

It is a matter for consideration whether the wear on the leading coupled flanges of engines of this class could not be reduced, without detriment, by increasing the guiding effect exercised by the bogie when running round a curve. One method of doing this would appear to be by increasing the strength of the bogie side control springs. But there also appears to be in many engines of this type some connection between the position of the centre of the whole engine and the relative side wear on the flanges of the various coupled wheels. Indeed, there seems to be ground for thinking that the wear on the leading coupled flanges is relatively less in those cases where the centre of gravity of the whole engine is appreciably ahead of the middle point between verticals drawn through the bogie centre and the trailing coupled axle.

« V » crossings of an angle as flat as 1 in 20 are exceptional, and have not been standardised. Such a crossing must have a very long gap; and, although this derailment took place before the wheels in question had reached the gap, its use in a situation such as this, where high speeds are possible, undoubtedly throws a heavy stress on the check rail and its fastenings, even when gauge and clearance are correct. While there is no evidence to show that any failure or movement of the check rail took place, Colonel Anderson thinks that the desirability of substituting a worked movable frog for the crossing at this junction is for consideration by the company, as it would provide continuous support for the flange of the outer wheel, thereby reducing the risk of derailment and also avoiding the wear on the nose. The importance of the maintenance of exact track gauge, check-rail clearance, and super-elevation is also clearly shown by this derailment.

Colonel Anderson summarises his report thus :

1. This accident illustrates the care which is necessary both in fixing and observing maximum speeds, even when they are relatively high.

2. Close co-ordination of the permissible limits of wear or variation of wheel gauge, tyre contour, track gauge, and check rail clearance is particularly necessary where high speeds are possible.

3. The desirability of increasing the guiding effect of the bogies of engines of this class also appears to merit consideration.

4. The substitution of a worked movable frog for the « V » crossing at this junction should be considered.

5. A more exact method of gauging tyres under working conditions seems desirable, with a view to fixing definite limits of permissible wear. I understand that the company's chief mechanical engineer is already considering this.

6. Any means, such as lubrication of the check rail, which will reduce the friction between tyre and check rail, would probably also reduce the risk of climbing of the flange such as occurred in this case.

7. The use of deeper flanges, though their effect cannot be directly estimated in a case such as this, might, perhaps, have slightly lengthened the time taken by the flange to mount the check rail. Derailment might thus have been delayed long enough for more favourable conditions to be re-established, and so have been avoided.

II — **Derailment at Kent House, Southern Railway, 23 January 1931.**

Colonel Anderson has also reported on the derailment of the leading and intermediate coupled wheels of the engine — No. E. 853, four-cylinder, simple, 4-6-0 type, « Lord Nelson » class — of the up « Golden Arrow » express boat train from Dover to Victoria, at a facing connection from the up main to the up local line. The intermediate wheels appear to have been re-railed at the crossing of the junction connection, and the leading wheels were re-railed at a trailing connection from the up local line 880 yards further on. The driver was unaware of the derailment, and the train arrived at Victoria on time. The derailed wheels dislodged a check rail at the luggage level crossing in the station, and carried it forward for 63 yards, and then dropped it in the *six-foot* (the italics are our own) clear of both running rails.

The point of derailment is 53 chains west of Beckenham Junction signal-box. From that box there is a curve of about 95 chains radius, left-handed in the direction of travel, followed by 66 yards of transition, 16 yards of straight and then by a right-handed curve of about 33 chains radius on which is the facing junction where the derailment occurred.

None of the witnesses criticised the speed of the train, and the driver said he passed Beckenham Junction at about 40 m.p.h., and observed the speed restriction of 40 m.p.h. through the connection at Kent House. It should be noted, though, that the guard recorded the train as 1 minute late at Bickley Junction, and that it made up 2 minutes by the time Herne Hill, 9.77 miles further on, was passed. The time allowed for that distance was 12 1/2 minutes, or an average speed of 41.22 m.p.h.

At the time of Colonel Anderson's inspection, the road appeared to be in good order, and the small variations in gauge or super-elevation on the curves approaching the junction were not such as might be expected to set up oscillation of the engine or by themselves to cause derailment.

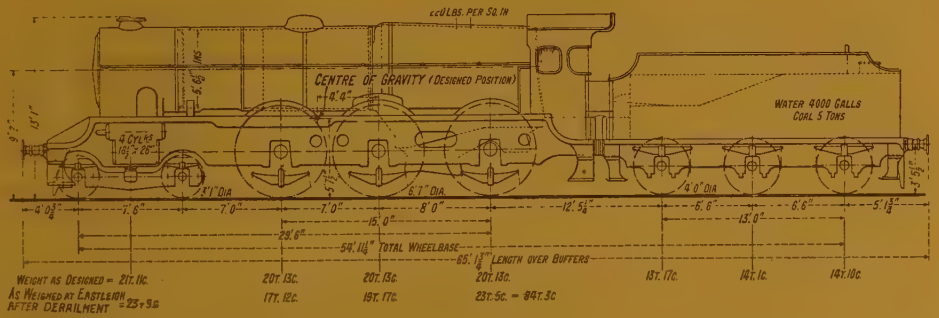
On a 33-chain curve 3 inches superelevation is, by calculation, correct for a speed of about 41 m.p.h., which, therefore, agrees closely with the maximum speed laid down. The gauge at the point of derailment was found to be correct when examined immediately after the accident. The crossing was in good order. The portions of the nose and wing rail which were worn had been built up by welding on 18 January, in accordance with the company's latest practice, and it is of interest to record the fact that there was no evidence of failure of the weld in spite of the severe blows which it must have received from the two derailed wheels.

The check rail clearance was 1 7/8 inches, *i. e.*, 1/8 inch more than the standard 1 3/4 inches, owing to side

wear of the check rail. The contact face of the check rail was brightly polished by the flanges of passing wheels, and had several vertical marks which certainly suggested that some of them had climbed.

At the time of derailment the engine had run about 57 000 miles, and had, therefore, nearly reached the mileage, about 65 000, at which heavy repairs usually are found necessary for this class. The engine, after derailment, was weighed at Eastleigh, with the results shown on the diagram. The discrepancies in the weights so found and in the design were, no doubt, due to the derailment. None of the springs were broken.

The flanges of the leading and trailing bogie wheels, which were originally of the British Standard « A » profile, were



Total weight on coupled wheels			61 t. 19 c
—	—	of engine in working order	83 t. 10 c.
—	—	— empty	75 t. 16 c.
—	—	of tender in working order	42 t. 8 c.
—	—	— empty	19 t. 11 c.
=	—	of engine and tender in working order	125 t. 18 c.
—	—	— — — empty	95 t. 7 c.
Brake power :			
	Engine		42.2 tons.
	Tender (6-wheeled)		22.6 tons.
Percentage brake power :			
	Engine (weight on coupled wheels)		68.0 %
	Tender		53.3 %
	Engine and tender (weight on coupled and tender wheels)		62 %

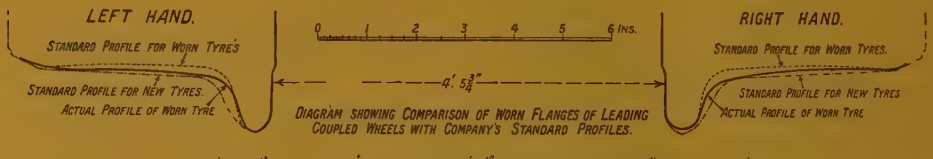
Fig. 5. — Diagram of Southern Railway « Lord Nelson » locomotive, with essential particulars.

within the limits of wear fixed by the company. The bogie trailing axle was very slightly bent, but not to an extent great enough to require replacement. There was a small mark on the flange of the right trailing bogie wheel which might have been caused by striking an obstruction. The flanges of the leading coupled wheels were originally of the British Standard « G », intermediate, contour. The tread of the right-hand tyre was worn about 3/32 inch hollow over part of the circumference of the wheel and rather less over the remainder of it; that of the left-hand wheel was about 1/8 inch hollow. The tickness of the left flange at a point 11/32 inches below the tread was 0.828 inch, *i.e.*, it was very nearly down to the minimum limit fixed by the company, the side wear being approximately 0.21 inch at this point. Figure 6 shows the comparison of these tyres with the company's standard « new » and « condemning » profiles.

The flange of the right-hand intermediate coupled wheel was worn hollow on the tread to the extent of about 1/16 inch. These flanges were originally of the « E », thin, contour. The flange of the right trailing coupled wheel was worn about 1/8 inch hollow on the tread, the left about 1/16 inch. These flanges were of the « A », thick contour. The total side wear of the trailing coupled flanges was slightly less than that of the leading coupled flanges. The gauging also showed small but distinct variations in the wear at different places on the circumference of all the coupled wheels.

Both the leading and intermediate coupled wheels bore marks on the tyres which seemed to have been caused by derailment or striking an obstruction. These marks were more numerous on

Fig. 6.


LEFT HAND.
STANDARD PROFILE FOR WORN TYRES
STANDARD PROFILE FOR NEW TYRES
ACTUAL PROFILE OF WORN TYRE
0 1 2 3 4 5 6 INS.
4' 5 3/4"
DIAGRAM SHOWING COMPARISON OF WORN FLANGES OF LEADING COUPLED WHEELS WITH COMPANY'S STANDARD PROFILES.
RIGHT HAND.
STANDARD PROFILE FOR WORN TYRES.
STANDARD PROFILE FOR NEW TYRES
ACTUAL PROFILE OF WORN TYRE

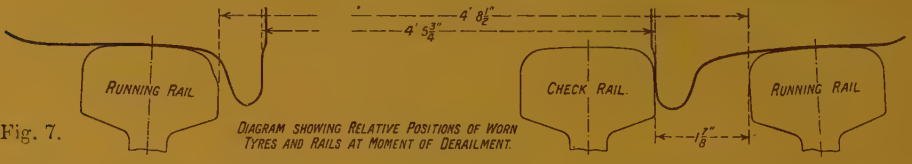


Fig. 7.

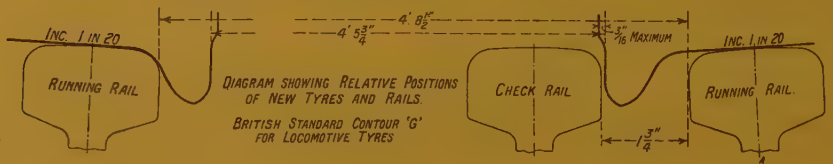


Fig. 8.

Figs. 6 to 8.

the leading than on the intermediate coupled wheels. The right leading flange had distinct deep dents at two places on the nose of the flange and another on the inside of the flange. The left leading flange had a distinct dent on the inside and a number of smaller dents, distributed in two groups, more or less opposite one another. The right intermediate coupled wheel had two noticeable dents, one on each side of the flange. The left wheel had a large dent on the outside of the flange and several smaller ones also on the outside of the flange nearly opposite to it. The designed hammer blow for each coupled wheel of this engine at 60 m.p.h., is as follows : Left leading, 0.75 ton; right leading, 0.31 ton; left intermediate, 1.51 tons; right intermediate, 0.61 ton; left trailing, 0.75 ton; right trailing, 0.31 ton.

Colonel Anderson therefore concludes that the derailment began by the climbing of the right leading coupled wheel on to the check rail. Having thus been released laterally, the leading coupled axle moved over bodily to the left, as might be expected on this curve, and its left wheel struck the left side of the nose of the crossing; the right-hand wheel of this axle continued to run along the head of the check rail to its end. Both leading coupled wheels then ran on the chairs until re-railed at the next crossing some 880 yards further on. Derailment of the right intermediate cou-

pled wheel apparently followed almost at once. It seems to have climbed the check rail at a point about 4 feet 10 inches from the nose of the crossing, *i.e.*, between 1 and 2 feet ahead of the point of derailment of the leading coupled wheels. This axle did not travel as far to the left as the leading coupled axle had done. The flange of the left intermediate coupled wheel struck the right-hand side of the nose of the crossing, and both intermediate coupled wheels were thus almost immediately re-railed, as is shown by the ending of the second mark on the head of the check rail. The throat of the crossing is approximately 3 feet 4 inches from the nose; so that both pairs of wheels were derailed before their left-hand wheels reached the gap in the crossing.

It is the opinion of the inspecting officer that this derailment was due to an unfortunate combination of several contributing causes. The first of these was high speed. In view of the evidence, and particularly of driver Chapman's statement as to the time made up by him, which is confirmed by the guard of his train, he thinks that at the time of derailment the speed restriction of 40 m.p.h. was not being strictly observed; the speed of the train was probably between 50 and 55 miles an hour when derailment occurred. For this driver Chapman must accept some measure of responsibility.

The report concludes generally in the same terms as that on the Weaver Junction derailment, including the remarks as to certain goods wagons with a pronounced shoulder on the inside of the tyre. Colonel Anderson's observations, in his summary in the Kent House case, as to the wear of the flanges, are, however, of greater length, and so we reproduce them. They read :

2. The side wear on the flanges of the leading coupled wheels of this engine was considerable, as is shown by figure 6 on the diagram attached. The total wear was slightly greater on the leading than on the trailing coupled wheels. At my request the company's officers examined in this respect the flanges of a number of their other engines of this (4-6-0) type. In the « Lord Nelson » class this feature only appears in a few of the engines examined, but in the other engines it appears to be fairly common.

In all the engines examined by them the position of the centre of gravity of the whole engine is appreciably in rear of the middle point between the verticals through the bogie centre and the trailing coupled axle. I have some ground for thinking that its position has some bearing on the relative wear of the different tyres of engines of this (4-6-0) type, and I think that this point, as well as the possibility of increasing the strength of the bogie control springs, or in some other way increasing the guiding action of the bogie on a curve, merits further investigation and consideration.

[656.1 (.42)]

The Scottish Motor Traction Co. Ltd.

(From *The Railway Gazette.*)

Fig. 1, p. 799.

The Scottish Motor Traction Co. Ltd., (S. M. T.) which was founded in June 1905, with an issued capital of just under £ 12 000, has had an extraordinary record of success. Beginning with a fleet of six Maudslay double-decked omnibuses, latterly increased to twelve, the first route operated by the company was between Bathgate and Armadale. This was afterwards abandoned in favour of the Edinburgh to Corstorphine route, which is only a distance of 3 1/2 miles. In those early days when the motor omnibuses had to meet the opposition of all manner of prejudice, it was found advisable to confine operations to comparatively short distances, and the next routes that were added were Edinburgh to Loanhead and from Edinburgh to the Forth Bridge, distances of six and nine miles respectively. In 1907 it was found necessary to increase the capital of the company to £ 25 000. Some idea of the progress that has been made since then may be gained from the fact that to-day the authorised capital stands at £ 1 800 000, with an issued capital of £ 1 224 076.

The present Scottish Motor Traction Co. Ltd. was registered in Edinburgh in August, 1929, as a result of reorganisation and reconstitution due to the completion of arrangements with the London Midland & Scottish and London & North Eastern Railways, together with certain amalgamations and other services. Among the companies now controlled in this large organisation, which is linked closely with the railway companies, are : W. Alexander & Sons Ltd.; Simpsons & Forresters Limited; Pitlochry Motor Co. Ltd,; Scottish General Omnibus Company; General Motor Carriage Co. Ltd; Scottish General (Northern) Omnibus Co. Ltd.; Midland Bus Services Limited. The directors of the company to-day are : Mr. A. J. Paterson (Chairman), Messrs. J. F. Follows, C. B. E., M. V. D. (Vice-President, London Midland & Scottish Railway), J. Calder (General Manager, Scotland, London & North Eastern Railway), John R. Gray, John A. Lindsay, and W. J. Thomson (General Manager), with Mr. George Oliver as Secretary. The first premises occupied by the company were at Bathgate, some twenty miles from Edinburgh and on the main road to Glasgow, but after a short time the headquarters were removed to Edinburgh where premises were acquired in Lauriston Street. Within two years these premises were found to be inadequate and a large garage was built at Fountainbridge, Edinburgh, and subsequent extensions to this property have been made from time to time until it now covers a floor area of nearly four acres.

The company have found it necessary to acquire works and garages in Broxburn, Bathgate, Armadale, Withburn, Linlithgow, Peebles, Glasgow, Dundee, Galashiels, Melrose, Selkirk, Chirnside, Duns and other places. Within recent times the site of the old gasworks belonging to the Edinburgh Corporation has been purchased and on it a garage for 300 vehicles has been constructed.

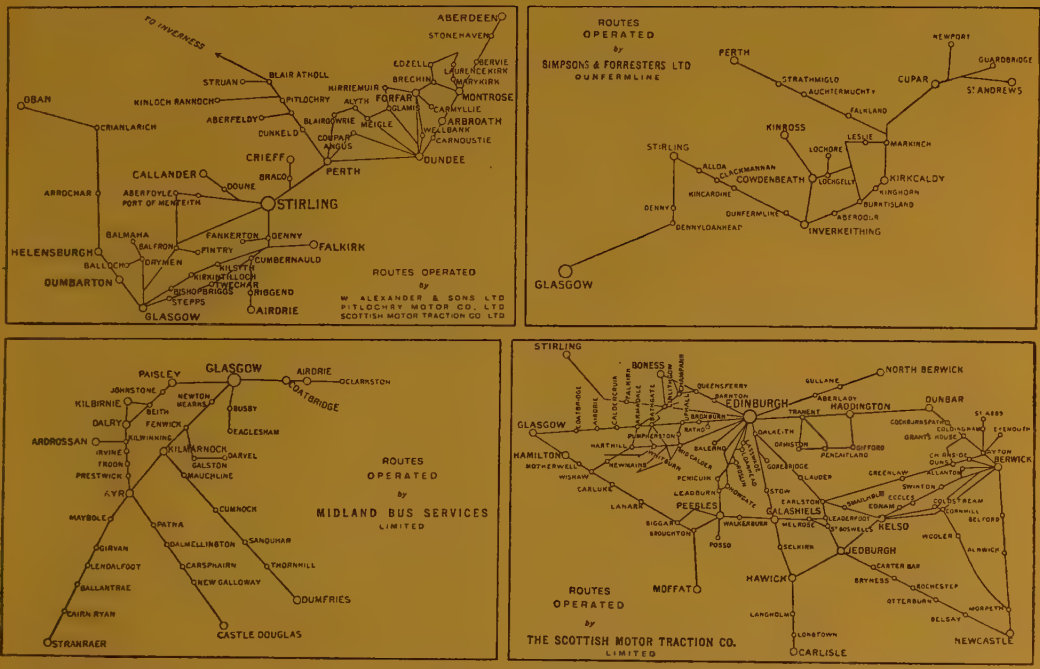


Fig. 1. — Sketch maps showing some of the many services run by the Scottish Motor Traction Co. Ltd. and Associated Companies.

The routes of the services of the company have gradually increased, and today they number about 100 and extend from Edinburgh westward to Glasgow, and eastward by Dunbar to Berwick-on-Tweed and Newcastle. On the north side of the Forth, the S. M. T. have headquarters at Dundee with routes extending along the Firth of Tay and north to Forfar, Kirriemuir, Alyth and Blairgowrie, while southwards they cover every part of the Border country and go down as far as Carlisle. At Newcastle and Carlisle they link up with the United Automobile Services and the Ribble Motor Services, whose routes cover the whole of the north of England. Within the past year the company has established a daily direct motor-coach service between London and Edinburgh.

Some of the ordinary long-distance services are operated on a limited stop basis, as between Glasgow, Dundee and Aberdeen, and from Glasgow to Crianlarich and Oban. The S. M. T. is also, by virtue of the railway interests now included, a party to alternative rail or road user of tickets in many places, in conjunction with the London Midland & Scottish and London & North Eastern Railways. The company has arrangements for the carriage of parcels and light goods on all standard routes, while in many districts, workmen's, market and other cheap fare tickets are provided. In many instances special services are operated in these connections to meet requirements, apart from the standard services which appear in the public timetables.

The map (fig. 1) indicates in outline the routes radiating from Edinburgh or in connection with those services which are operated directly by the S. M. T. Those

working to the east usually start from St. Andrew's Square, Edinburgh, just north of Princes Street and about opposite to the Scott Memorial. To North Berwick the service is at 15-minute intervals, while there is a 10- or 20-minute service via Musselburgh, some services terminating at Tranent, Pencaitland or Haddington and others running through to Dunbar, with hourly buses making the complete journey to Berwick and thence via Alnwick and Morpeth to Newcastle. Single-decker vehicles are used for all these services, of saloon types for the long runs to Berwick and Newcastle.

The double-deckers for the picturesque Balerno route also start from St. Andrew's Square at frequent intervals, similar vehicles being also used for the half-hourly service between Chambers Street (in South Edinburgh and providing a service on a route convenient for parts of the city) and Balerno. Hourly services to Pumpherston via Broxburn and Uphall also use Chambers Street, together with the Lauder and Earlston, Newcastle via Kelso, Coldstream and Wooler services.

A third departure station in Edinburgh is The Mound (by the Art Gallery, and winding along Princes Street Gardens). This is used only for the popular Forth Bridge and Queensferry services (10- or 15-minute intervals), with their extensions at 40-minute intervals to Bo'ness. Single-deckers are principally used, with touring coaches during the holiday season on the Forth Bridge services.

The principal Edinburgh departure station is, however, the Waverley Bridge, where some half-a-dozen stations are indicated by notice boards. First of these is the important 15-minute Edinburgh-Glasgow service (2 hours 20 minutes) via Bathgate, Airdrie and Coatbridge, with additional vehicles as necessary as far as Bathgate and Armadale. From the Glasgow end there are also local services to Armadale and Bathgate. Another service from Waverley Bridge is that to Linlithgow, Falkirk and Stirling (half-hourly), hourly services continuing to Bridge of Allan and the intermediate services running either to Crieff or to Callander, thus giving a two-hourly through service to each. Another Edinburg-Glasgow route is also served from Waverley Bridge at hourly intervals, via East and Mid Calder, Witburn, Shotts, Wishaw, Motherwell and Hamilton (3 hours 12 minutes throughout), and intermediately on Saturdays and Sundays to Mid Calder or Oakbank.

Single-deckers are used for all these services, but on the southern series of routes to Penicuik, Peebles, etc., both single-deckers and double-deckers are used. These services, on leaving Waverley Bridge, turn into Princes Street, and then reach the south side of the city by crossing the North Bridge. The main series is that to Lasswade or Penicuik, with a second series to Gorbridge, Rosewell and Middleton, with several variations of route, and for those which are not parts of the longer services double-deckers are principally employed. The main routes, by the continuation of services, get frequent facilities, and to most destinations the interval is but rarely longer than 30 minutes, and in some instances and at certain times much less, as in the case of Penicuik and Gorbridge. On the longer routes, Peebles and Walkerburn, have an hourly service (with occasional route variations), with intermediate services to Peebles on Saturdays and Sundays. Other Waverley Bridge services at suitable intervals are to Pathead and Blackshiels, and to Galashiels, Hawick and Carlisle.

Local services.

The S. M. T. also operates a number of local services between various centres, of a cross-country character, as between Berwick, Kelso, Jedburgh, Galashiels, Peebles, Hawick and other places, and to and from Newcastle as well as locally,

but these need not be set out in detail, as they are shown on the map.

Another series of services run from Dundee to Forfar and Brechin; Coupar-Angus, Blairgowrie, Newtyle and Alyth; and Errol and Perth. From Perth there are also services to the same places, from Stirling to Aberfoyle, Perth, Dundee and Aberdeen, while other centres are Falkirk, Grangemouth, Airdrie and Kilsyth.

From Glasgow the services are more particularly those of W. Alexander & Sons Ltd., and these provide, besides the long-distance services to Dundee and Aberdeen, a wide selection of local services connecting Glasgow with Falkirk, Stirling, Dumbarton and Helensburgh, etc., or based upon these centres. A peculiar feature of the S. M. T. and associated services is that, due to the intervention of the Firth of Forth, many places on the east side of Scotland (Dundee, Aberdeen, etc.) are now more conveniently given road services from Glasgow than from Edinburgh which requires a diversion west to Stirling before the north side of the Firth of Forth can be reached.

South of Glasgow the Midland Bus Services Limited provide facilities to Paisley, Ardrossan, Ayr, Kilmarnock, Stranraer, Castle Douglas and Dumfries, and eastwards to Coatbridge, Airdrie, and Clarkston. A further series is that of Simpsons & Forresters Limited, centring upon Dunfermline, but extending to Stirling and Glasgow, Kinross, Kirkcaldy, Perth and St. Andrews.

The S. M. T. and its associates are, of course, concerned in a number of special long-distance services (apart from special tours). These usually start from the S. M. T. inquiry office at 45, Princes Street, Edinburgh. One is the 9.30 a.m. to Inverness, due 6.10 p.m. Then there is the Glasgow-Galashiels-Newcastle-Whitley Bay-Blyth service in conjunction with United Automobiles Limited (many of the Newcastle services are joint with this concern).

The Scottish General Omnibus Co. Ltd. also has a series of routes centring upon Dunfermline, whilst the Scottish General (Northern) Omnibus Co. Ltd. brings the Aberdeen and Inverness areas into the S. M. T. association.

Tourist traffic.

In addition to their ordinary services the company deals with very heavy tourist traffic during the summer months, both for private parties and organised tours.

The S. M. T. tours are recognised as among the finest in this country, and from a scenic and historical point of view afford visitors an unrivalled opportunity to explore the most famous places in Scotland. Throughout the summer regular tours run from Edinburgh to the land of Scott; the abbeys of Melrose, Dryburgh, and Kelso; Tantallon and Dirleton Castles, Dunbar and North Berwick, Bamburg Castle, Flodden Field, and Norham Castle; St. Mary's Loch, Moffat, and Selkirk; the Tweed Valley and Traquair; the land of the Border Rivers; Linlithgow Palace and Torphichen; Dumfries, Dalveen Pass, and Biggar; the Trossachs; Inchmahome, Lake of Menteith, and Aberfoyle; the land of Rob Roy; Loch Lomond and Loch Earn; Loch Tay; the Pass of Killiecrankie, Pitlochry, and Amulree; the Burns country; round Edinburgh and neighbourhood. Cruises to the island of Inchcolm by a motor yacht owned and operated by the company are also a regular feature of the summer programme. Several additions have been made to the touring programme for 1931, and include a five days' tour of the Scottish Highlands, another to the Isle of Skye, as well as a two-days' tour to Oban and the island of Iona and other historic districts.

Training of drivers and conductors.

As the staff of drivers and conductors numbers over 1 000, the greatest care has

to be exercised in selecting and training men suitable for the duties. The procedure adopted by the company is that each applicant is first interviewed by an official to ensure that he is at least of average intelligence and fitness. If the applicant passes this preliminary test, investigation is then made as to his character, ability and experience, and if this is satisfactory, he is then passed on to the medical adviser, Dr. McKendrick, who has made a special study of industrial conditions. Dr. McKendrick passes the men through a medical, physical and mental examination, and then advises as to the best men for each particular class of work. Those who pass the doctor are then, if engaged as conductors, put through a training school, where they are instructed in the handling of tickets, making up of waybills, and the company's rules and fares. On passing the school examination they are then sent out on the routes to learn the different places through which the bus passes, and generally how to conduct a bus. In the case of drivers who have passed the doctor, the men are also put through a course of training, and receive instruction on the various types of vehicle which the company have in their service. The drivers' course includes instruction on the engine, gear-box, back axle, carburettor, magneto and other parts, so that in the event of a vehicle giving trouble on the road, the driver has a very good idea of effecting a temporary remedy, or at least of giving accurate information to headquarters if the breakdown should be of a serious character. After passing through the school, drivers are, if necessary, given further instruction on the road, and are then put on the regular service to learn the bus routes. When a driver is thought to be proficient in his duties he is tested by a foreman driver, and, if passed, is put forward for his public service licence. All drivers and conductors are licensed by the authorities before they are put in charge of a vehicle.

System of maintenance.

The omnibus maintenance system is carried out on very thorough lines, many of its details showing clear evidence of the long experience gained since the services were started over twenty years ago. The original design of the Fountainbridge premises, together with the additions of later date, render the routine of maintenance smooth and efficient. On returning to the garage at night, each omnibus is swept out and washed, then put into its bay to receive certain mechanical attentions. The engine is examined for oil nightly, each gearbox and back axle being refilled with oil once a week. During the examination of the gearbox, mechanics go over the whole of the transmission and clutch mechanism. A special staff of men, drawn from the various departments, is detailed to examine every vehicle before it goes out for duty each morning, these men commencing work at 6 a.m. The men from the steering department go over all the steering gears, one man taking the odd-numbered and the next the even-numbered vehicles. The same system is carried out in respect of what is termed the « Back end squad », the duty of these men being to examine the brakes and all mechanical parts behind the gearbox. Men from the tyre department examine all tyres for cuts and air pressure, replacing tyres on any spare wheel which may have been changed during the course of the previous day's work. The whole details of the night supervision of the machines is carried out on similar lines, and thus the wear and tear is kept within strictly limited proportions.

Machinery equipment.

The stores are conveniently situated for serving the ground-floor and first-floor workshops, the respective sections being arranged on each floor in a separate two-storey division. Part of the upper storey is used for the garaging of

service vehicles and private cars, a very large business being done in all kinds of repairs and overhauls for private customers. Access to the upper storeys is provided by means of a large lift, capable of accommodating the largest vehicles of the fleet. Seventeen centre lathes of various makes are in use, four turrets, three capstans, seven milling machines, a gear cutter, two shapers, a slotter, ten drilling machines of various capacities, two borers, eleven grinding machines (including crankshaft and cylinder grinders) two heat-treating ovens, three power hacksaws, a surface table, straightening press, mandrel press, tyre press, sheet-bending and folding machines, swaging machine, power hammer, compressor, three tyre inflators, pneumatic tyre remover, vulcaniser, three portable grinding machines, and four portable drills. In addition to the above, there is a wide range of special appliances of the company's own design and manufacture, such as burning-in machines, engine test stands, and machines for boring all types of bearings used on the different makes of engines, these being of the hand-operated variety, whereby no scraping of bearings is necessary. A very high standard of workmanship prevails in all the departments of the works, and the chief engineer's returns prove that the cost per vehicle overhaul has been reduced to a very low figure.

At Valleyfield, Edinburgh, the S. M. T. has its body-building, rebuilding and repair shops, and here almost as much accommodation is provided for private firms, repair, maintenance, overhaul, etc.

In Lothian Road the S. M. T. has its show rooms for private cars and motor supplies, the makes principally shown being Citroen, Sunbeam, Buick, Minerva and Austin. In the Haymarket there is a corresponding depot for commercial vehicles, principally Chevrolet, Buick and M. G. In Roseburn Terrace there are extensive premises for the repair of private cars and other vehicles, with no fewer than 110 lock-up sections, believed to be the largest of the kind in Edinburgh. Repair work is principally associated with Sunbeam and Chevrolet vehicles, but the depot is also a general public supply. It is also a depot for many specialities, including Tecalemit.

The general office work and accounting premises are centralised at the head offices in 49, Queen Street, the Publicity Department having its own premises at 41, George Street. In Princes Street the S. M. T. has a well-equipped inquiry and booking office for public use.

We are indebted to Bailie Wm. J. Thomson, General Manager, Mr. J. Inglis Ker, Publicity Agent, and various officers of the S. M. T. for assistance in the preparation of this article; and also to the London Midland & Scottish and the London & North Eastern Railways for co-operation and assistance.

MISCELLANEOUS INFORMATION.

[625. 235 (43]

1. — The Pintsch electric train-lighting system.

Figs. 1 and 2, pp. 804 and 805.

(*The Railway Gazette.*)

It is now 25 years since the German State Railways began to experiment with electric lighting for railway coaches. After testing many systems, varying widely in type, including those which operate on a purely constant current or constant voltage method of regulation and those which employ various forms of self-regulating dynamos, the conclusion was reached that a system with a plain shunt dynamo and a simple form of voltage regulator presents the most marked advantages.

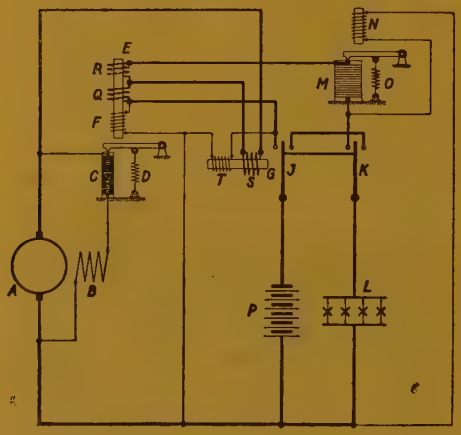


Fig. 1. — Diagram of connections of Pintsch electric train-lighting system.

Of the many types of voltage regulator which were available for this purpose, that of the carbon pile form, in which variations in resistance are brought about by variations in pressure on a column of carbon plates, was found to be most suitable.

Great importance was attached to securing a method of regulation which would effectively control the battery-charging current in such a way as to meet the actual requirements of the battery throughout the widely varying conditions to be met with in service. It can easily be understood that if the rate at which the charge is delivered and the extent of the charge do not conform to the actual requirements of the cells, extensive damage may be caused, resulting in shortened life of the battery and greatly increased maintenance costs.

The extensive testing work which the German State Railways carried out with various kinds of electric train-lighting systems indicated that the system manufactured by the Julius Pintsch Aktiengesellschaft, of Berlin, was the one which most completely met all requirements. Apart from the advantages gained by the adoption of the carbon-pile form of regulator and the very sound design of the Pintsch apparatus, the advantages of this system were found to arise from the following features :

1. Its success in adapting the charging current to the momentarily existing state of charge of the battery and the requirements of the service.

2. Maintaining constant charging voltage throughout the whole journey subject to provision which is automatically made for diminished charging voltage when lights are not in use and for full charging voltage across the accumulators when lights are full on.

General arrangement of Pintsch system.

In the diagram, figure 1, A represents the commutator of the dynamo, B the exciting winding thereof, and C a regulating carbon pile connected in the exciting circuit and consisting of individual discs or plates of carbon. This pile is compressed by the spring D, which compression is to a certain extent relieved by the pull of the magnet E, which is excited through the coil F by the voltage to be regulated.

It is a characteristic feature of the carbon

pile that it considerably increases its electric contact resistance when the pressure upon it decreases. This means that the pile resistance increases with increase in the voltage to be regulated and thus such increase in voltage is minimised and, owing to the sensitiveness of this means of regulation, may be said to be avoided.

By the provision of special means for compensating the forces, absolute equilibrium of the lever applying the pressure is obtained over the whole range of movement of the regulator as long as the excitation of the magnet, *i. e.*, the voltage to be regulated, is at the correct value. The effect is that only a very slight deviation of the voltage from the normal tends to drive the regulator in one direction or the other, as a rule somewhat farther than would be required for the actual correction of the voltage deviation. The regulator therefore causes the voltage to be maintained at the desired constant value throughout the entire range of control. Essential conditions for this are of course that friction in the apparatus, variations due to temperature in the coils, residual magnetism and coercive force in the iron shall all be reduced to a very low value. This can be said to be the case to a particularly high degree in the Pintsch system.

G is a change-over magnet, which connects the dynamo with the battery and the lighting network when the speed of the train and voltage of the generator exceed a certain figure. When the train is at a standstill, or only travelling at low speed, the magnet G will have released its armature. The battery P is then in direct connection with the lighting network L through the two switch levers J and K. As soon as the dynamo, on reaching a certain speed, has generated the required voltage, which is somewhat above the battery voltage, the magnet G, under the action of the voltage coil T, attracts its armature. The consequent closing of this switch connects one terminal of the generator through the series coil S, and then on the one hand through coil Q and switch lever J to the battery, and on the other hand through coil R and switch lever K to the lighting network L.

In this latter circuit is provided a second carbon pile M, which automatically brings about such changes in resistance in this circuit as are necessary to maintain correct voltage across the lights at all lamp loads and at any value of the generator voltage. This carbon pile, as in the case of that in the generator field circuit, is also under initial compression, in this case by spring O, and

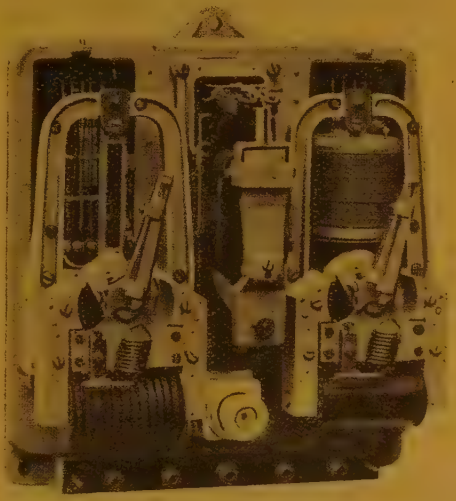


Fig. 2. — Voltage regulator details.

such compression is partly relieved by the magnet N, the exciting coil of which is connected across the lighting circuit.

It will be noted that this second carbon pile is only connected in circuit with the lighting network when the train is running at a speed sufficient to cause the dynamo to charge the battery. The coil S, situated on the change-over magnet, has the effect of confirming the contact of the switch after this closes and assists the opening of the switch immediately a return current flows from the battery back to the dynamo when the speed of the latter falls below a certain minimum.

Under the action of the coil F the generator voltage is regulated to the somewhat decreased charging voltage required during day-time running, independently of the speed of the dy-

namo. To increase the charging voltage to the normal value during night running, the lighting current traverses the regulator coil R, which acts with a weakening effect. In this way the coil F is compelled to increase its number of ampere-turns exactly by the number of ampere-turns generated by coil R. The rise in the generator voltage is accordingly proportional to the amperage of the lighting load.

In order, in the case of a wholly discharged or partly short-circuited battery, to protect the generator against excessive overload, the charging current is passed through the regulating coil Q, the magnetising action of which supports the voltage coil F in reducing the dynamo voltage and preventing excessive charging current. The adaptation of the value of the charging voltage to the demands of the lighting circuit results in a greatly increased life of the cells, more particularly by avoiding overcharging during the summer months — a feature which distinguishes the Pintsch system from all others.

The Pintsch system, employing as it does a constant charging voltage, charges with a decreasing current, and in this manner reduces overcharging, at the same time giving a more complete state of charge and diminishing the danger of sulphation.

Once the maximum charging voltage is attained, it is kept up until the next stop is reached, and acts continuously in an anti-sulphating manner.

The generation of the full-charging voltage at night ensures that the accumulators are fully charged at the end of a night's run, and thus cells on cars taken out of service immediately afterwards do not sulphate if left idle.

In those systems from which special means of regulating the lamp voltage are omitted the lamps are frequently subjectd to excess voltage, the ill-effects of which can only, in part, be avoided by suitably proportioning the lamp filaments or at the sacrifice of lamp candle-power when the train is at a standstill. With the Pintsch system, on the contrary, the lamps during travelling receive exactly the same voltage as when the car is at rest. In this manner lamp renewal costs are substantially decreased, as compared with systems operating without lamp regulators.

Owing to the application of a constant charging voltage with decreasing charging currents, the Pintsch system accommodates its battery charge automatically to the existing requirements. The advantage of this is that cars with the Pintsch lighting system do not require adjustment of the charging rate with changes of itinerary or changes of season.

In the regulation of dynamo and lamp voltages in this system no « make » and « break » of contacts takes place and the movement of all parts is reduced to the smallest possible amount. Consequently burnt and worn connections are eliminated and wear of all moving parts is reduced to a minimum. These facts account for the high degree of reliability and lasting qualities of the apparatus. The details of construction of the voltage regulator are shown in the illustration, figure 2.

The particular merits of the Pintsch system as regards high reliability in service, sparing treatment of batteries and lamps, and the advantage of never requiring any adjustment, were the reasons which decided the German Railways to adopt this system as standard, and about 13 000 cars have already been equipped.

---

625 .245 (.42)

2. — Screw-over side tip wagons.

Figs. 4 to 6, p. 807.

(*The Railway Gazette.*)

The Great Western Railway (England) has recently taken delivery of twenty 15-cubic yard capacity side-tipping wagons of a new design for service in the Engineer's department.

The leading dimensions of these wagons, which were built by the Metropolitan-Cammell

Fig. 4. — Four Great Western Raiiway Engineer's department side-tipping wagons discharging simultaneously.

Fig. 5. — General view of new 15-cubic yard capacity side-tipping wagons.

Fig. 6. — Side-tipping wagon fully tipped, showing underframe construction.

Carriage Wagon & Finance Co. Ltd., at their Saltley, Birmingham, works, are as follows :

Length over buffers	24 feet.
Length inside body	21 ft. 3 in.
Width inside body	7 ft. 9 in.
Width overall	8 ft. 9 1/2 in.
Height of floor above rails	5 ft. 4 1/2 in.
Maximum height of sides above rails	7 ft. 1 1/2 in.
Maximum angle of tipping	40 degrees.
Load	14 tons.
Tare	9 tons 10 cwt.

The ordinary type of tip wagon rotates about a longitudinal axis on the centre line of the vehicle, but this wagon has a body which can be tipped over to either side whilst the underframe remains stationary, so that the contents may be discharged clear of the track, and, further, the body moves over to the side from which it is intended to discharge before it begins to tip, and during tipping continues to move sideways. The body is so arranged that its centre of gravity does not rise at any stage of operations. The wide door opens automatically as the body is being tipped, but it is controlled by gearing, which enables the body to be partly tipped before the door opens. A suitable safeguard is provided to prevent the possibility of the body moving too far away from the underframes, and locking gear automatically locks the body when it has been returned to its central position.

The operation of tipping the wagon can be accomplished by one to three men, according to the weight of the material in the wagon, and whether the cant of the road is with or against the tipping. The time taken to discharge the contents and return the body to its normal position is about 5 minutes.

[621. 133.7 (.42)]

3. — The new Gresham feed water heater.

Fig. 7, p. 809.

(From *The Railway Gazette.*)

The accompanying sectional drawing shows the construction of the new Gresham feed-water heater manufactured by Gresham & Craven Limited, Manchester. In this design the heater his mounted on the side of the boiler as much in the steam space as possible. The feed water from the injector is connected from the flange A and passes via back-pressure valve B to heater nozzle C, where it is given sufficient velocity to cause a slight vacuum around cone D, which draws in steam, the latter being immediately condensed and its heat given up to the water. Similar action takes places at cone F, resulting in the final mixture leaving this cone almost at steam temperature. Special arrangements are made for removing the cones easily so that any trouble caused by heavy scale deposits can be readily overcome by inserting a fresh set of cones, whilst those removed are cleaned in acid. The heater is applicable to feed water from pumps or exhaust steam injectors.

This type of feed-water heater is fitted, among others, to the London & North Eastern Railway high-pressure locomotive No. 10000, and Mr. H. N. Gresley, in his paper on *High-pressure Locomotives*, read before the Institution of Mechanical Engineers (1), made some very interesting remarks relative to the methods employed in the boiler of that locomotive for dealing with the feeding and circulation of the water. He stated that temperatures up

---

(1) See *Bulletin of the Railway Congress*, May 1931, p. 377.

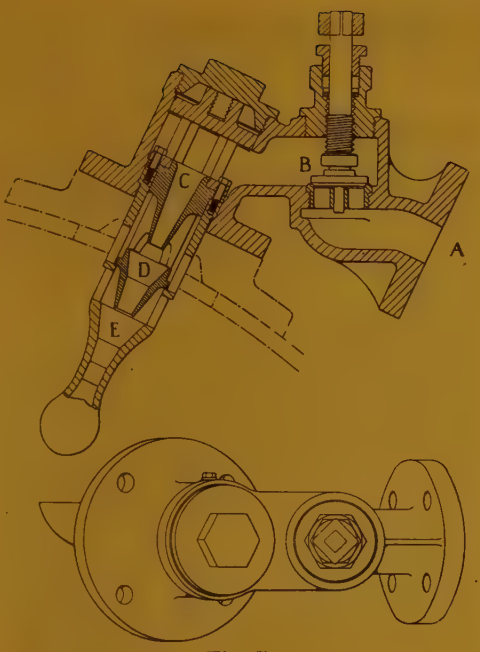


Fig. 7.

to 430° F. (221° C.) were obtained with a saturated steam temperature of 460° F. (238° C.).

By the use of the new Gresham feed-water heater the temperature of the water entering the boiler would, assuming a boiler pressure of 180 lb. per sq. in., never fall below 340° F., and would probably range from 355° to 360° F., this temperature being in no way dependent upon the driver or fireman.

The advantages claimed from this increase in feed temperature are :

1. decreased maintenance cost, and 2. increased evaporation from a given boiler and also per lb. of coal. The net increase in evaporation per lb. of fuel by this method of live steam feed heating has been shown to vary from 2 1/2 to 8 %, depending on the type of boiler and its normal circulating efficiency. The makers and patentees have demonstrated an increase of thermal efficiency of 2 1/2 % on a high-class modern locomotive boiler.

We noted with interest that in dealing with the points regarding the washing out of locomotive boilers, Mr. Gresley in his paper said that whilst engines of the *Pacific* type, in the same link as No. 10000, require washing out after running 1 000 to 1 500 miles, No. 10000 itself, with the new feed heater, ran 5 000 miles without washing out, and when opened up it was found that the boiler was exceptionally clean and the tubes in good condition.

NEW BOOKS AND PUBLICATIONS.

[621. 13 (02, 621 .33 (02. 625 .2 (02 & 656 .23 (02]

CORINI (Félice), Engineer, Professor at the Royal School of Engineers, Bologna. — **Construzioni ed ezercizio delle ferrovie.** Volume secundo : **Impianti.** (**Construction and operation of railways.** Second volume : **Fixed plant,** 2nd edition). — One volume (9 1/2 × 6 3/4 inches) of 446 pages with 298 figures and 4 inset plates. — 1930, Turin, Unione Typografica-Editrice Torinese, 28, Corso Rafaello.

In the Bulletin of December 1929 a brief review was given of the first volume of the treatise by Mr. Felice Corini, the title of the volume being: *Meccanicà della Locomozione (Mechanics of locomotion).*

The subject of this second volume is the constrction and equipment of railway lines. It comprises the following chapters :

I. The lay-out of the line.
II. The equipment of the track.
III. The stations.
IV. The signals.
V. Safety apparatus and plant. Central cabins and block systems.

The choice of the lay-out of the line is examined from the economic point of view. The basis underlying the examination is the probable traffic, and the author discusses the methods which have been proposed for determining it. Another element which it is indispensable to know is the operating cost per kilometre, which is a function of the traffic. The author determines it by a method based on personal investigations, which consists in assuming a linear form for the law required and in calculating the coefficients, given the results of lines in operation, that are comparable to the projected line. He also puts into requisition the virtual lengths which differ according to the significance given to the equivalence of the lines. Then recalling the variation in inverse sense of the two terms composing the cost price — first costs and operating expenses — he makes an attempt at determining the most suitable gradient, adopting for the operating expenses a function of the second degree increasing with the gradient and, for the first costs, a decreasing linear function.

One paragraph in this first chapter covers the study of rather special economic problems by Launhardt and Schrutka. That indicating in detail the method to be followed and the documents to be drawn up for securing the necessary authorisations and for submitting the projected lay-out and for the survey in the field is of a more practically useful character. The permanent works are the occasion of a discussion of the considerations relating to the stresses to which they are subjected and of the development of the theories regarding the dynamic effects in metal bridges.

In the chapter on the equipment of the track, the author deals with the question of the calculation of sleepers and rails, assuming the latter to be laid on elastic supports and on rigid supports. He gives Zimmerman's formula.

The constituent elements of the track are described, selected examples being given of the most recent applications on the Italian Railways. The laying of the track in curves and vertical easement curves are submitted to practical rules forming the conclusion of the theories developed in the first volume. The geometric lay-out of track appliances is stu-

died and formulae are given for a large variety of cases. The lay-out of turnouts is shown by considering that the points are straight ones.

The study of stations which forms the subject of chapter III is arranged so as to cover a successive examination of the plant essential to the various services. Special attention has been paid to marshalling yards and their modern equipment : brakes, signalling and manipulation of the points. An interesting paragraph is devoted to the theoretical and experimental study of tunnel ventilation plant.

The Italian system of signalling is described in chapter IV, but the author also mentions the essential features of the American, English, French and German systems of signalling. He describes tests and interesting applications of daylight signals and cab signals.

Chapter V contains a general theory of interlocking systems and examples of its application to central cabins for the operation of signals and points, with descriptions of hydraulic, pneumatic and electric apparatus, referring more particularly to recent equipment on the Italian Railways.

The chapter closes with a study of the block system. In semi-automatic block apparatus, the author has selected, in support of his account, those of Hodgson and Cordoni-Servettaz. In enlarging upon the principles of the automatic block, the author has considered the different forms of traction : steam, direct current and alternating current. The possibility of using the automatic block concurrently with alternating current traction is of interest in Italy, where its application is proposed for the new lines Rome-Naples and Bologna-Florence and on that from Bologna to Milan.

It is again a pleasure to pay tribute to the scientific qualities of the book. Nothing can satisfy the mind better and nothing can serve progress better than the systematic coordination of facts, theory, checked by experience, being used as an aid to empirical methods.

E. M.

[621. 392 & 69]

KOMMERELL (Dr Ing. O.), Direktor bei der Reichsbahn im Reichsbahn-Zentralamt für Bau-und Betriebstechniek in Berlin. — **Erläuterungen zu den Vorschriften für geschweisste Stahlbauten. (Commentary on the regulations affecting welded metal structures).** — One volume (8 1/4 × 6 inches) of 71 pages, 69 figures. — Third edition, revised and enlarged. — 1931, Berlin, published by Wilhelm ERNST und Sohn.

In the first editions of this work, published in 1930, under the title « Calculations, methods of construction and execution of welded railway bridges », the author, in the absence of official regulations, devoted himself to the determination of regulations for calculating joints formed by autogeneous welding and to show that these can be calculated with the same ease and the same certainty as rivetted joints, provided always that the principles upon which these calculations are based continue to be verified by comparison with the numerous practical tests being carried out so as to make them more complete and to ensure they are fully developed.

An official Commission appointed to investigate this question finished in the meantime its work and issued regulations for the calculation and the construction of welded structures. The third edition of Dr. Kommerell's work has been rearranged in consequence and now appears in the form of a commentary upon the official regulations together with nume-

rous examples of calculation, of developments in the methods of making joints and in buiding welded structures.

The first chapter deals with general questions regarding the structures assembled by welding : general prescriptions, welding materials, welding processes, calculations of welded joints, allowable stresses along the lines of the welds, methods of making joints, testing of the welders, test pieces, carrying out the welding and inspection of the work.

The additional prescriptions relating to the construction of bridges are examined in the second chapter : calculation of welded joints, design of these from a constructional point of view in this particular case.

The third chapter is given over to the tests to destruction of welded joints carried out in the Dresden Higher Technical School : the author shows that joints made in accordance with the official regulations give an amply large factor of safety.

The last chapter includes numerous examples of calculations of welded joints and covers most of the cases found in welded structural work, and especially in the building of bridges. The work will thus be warmly appreciated by engineers desiring to follow the progress of new methods of making joints, the economic importance of which at the present time is occupying the attention of all builders.

A. C.

[385. 15. (.494)]

DIETHELM (Dr. E. A.). — **Die Verstaatlichung der Schweizerichen Privatbahnen durch den Bund und ihre finanziellen Auswirkungen auf die Schweizerischen Bundesbahnen von 1903-1913. (The nationalisation of the Swiss private railways and its effect on the financial situation of the Swiss Federal Railways from 1903 to 1913).** — 1930, Lachen; published by the Buchdruckerei « Gutenberg ». 1 vol., paperbound (9 × 6 inches), of 254 pages, with map.

The system of the Swiss Federal Railways has been formed almost exclusively by buying up the concessioned lines.

From the commencement of the railway era, the partisans of the system of concessions had triumphed over those who advocated the building and operation of railways by the State.

The concessions granted by the Cantons and approved rather readily by the Federal Assembly were far from being drawn up on a single model. The desire to stimulate private enterprise resulted more often than not in the presence of clauses favourable to the concession holder.

Under this system, the railways developed fairly rapidly, more rapidly than was foreseen by the general plan outlined by Stephenson, but local interests came before the general interest and this period is characterised by a keen competition between the Private Companies.

In 1872, a new act made it necessary to have a State concession for building and operating railways. The grant of new concessions or the renewal of those previously granted by the Cantons became a Federal question. Afterwards a need was felt for standardising the form of the concession deeds, particularly the clauses containing the conditions of purchase and a « normal concession » was drawn up. However, the persons responsible for drawing this up appear to have had in mind more the facilitating of the financing of the undertakings by guaranteeing the shareholders against premature purchase rather than the protection of the State interests. During

the first period, as a consequence of the development of the lines beyond requirements, competition was seen to reduce the rates to the extreme limits and to bring about strained financial situations, but building was still carried on economically. This second period is marked, says the author, by a veritable frenzy of building.

During the crisis resulting from the circumstances mentioned, the insufficiency of the keeping of the railway accounts, the unsound financial principles of the exaggeration of the first cost account and the grievous consequences of a purchase effected under these conditions had become clear to all. In 1883 it was decided not to purchase the railways at the first date (1888), but an act was passed modifying the system of keeping accounts used by the railway companies. A period of preparation for nationalisation then began, leading to the passing in 1896 of a second Accounts Act, strengthening the position of the Federation in regard to the Companies. On 15 October, 1897, the Federal Assembly passed the « Law concerning the acquisition and the operation of the railways for and on behalf of the Federation and the organisation of the Administration of the Swiss Federal Railways ». This law was ratified by the popular referendum of 20 February, 1898. It provided for the purchase, on the first opportunity, of the five great Swiss railways on conditions laid down in the legislation and in the concessions, while leaving the Federal Council free to negociate the free purchase, taking the same rules as a basis for the estimation of the purchase price.

The author examines in succession the manner in which the five great railways : the Swiss Central Railway, the North-East Railway, the United Swiss Railways, the Jura-Simplon and the Gothard passed under Federal administration. He first of all explains their constitution and the amalgamations, as a result of which they had attained their development at the time of purchase. Actually, the five railways were acquired by contracts entered into with the Companies and, if the case arose, with the Cantons or foreign organisations which had taken part in financing them. The author describes the long negotiations which preceded nationalisation and the laborious discussions regarding the evaluation of the bases of purchase. He considers that the latter was heavy for the State.

In a third part, the author analyses the financial influence of the policy of purchase on the development of the Swiss Federal Railways from 1903 to 1913. He examines the charges resulting therefrom, the measures taken in regard to rates and the pay of employees, and the constructional expenses which became inevitable as a result of the conditions under which the lines had been built.

The general conclusion of the author is that the circumstances in which the Swiss private railways had been formed and developed were to lead inevitably to amalgamation by nationalisation and that the purchase, as regards both the conditions in which it was effected and the general situation of the railways, has weighed heavily on the finances of the Swiss Federal Railways.

The book is provided with copious references, and contains numerous statistical data of an economic and financial character taken from the best sources.

E. M.